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Do Automation and Artificial Intelligence Contribute to Improving Human Wellbeing, Resilience, and Collaboration?

Invited paper

Florin Gheorghe Filip

Abstract

The paper is a follow-up of two other rather recently published articles [1] and [2] that were meant to present a concise and rather fair image of computer-supported human wellbeing, resilience, and collaborative decision-making. Since the publication of the above papers (in December 2021, and March 2022, respectively), many significant technology advances, real-world applications, and intellectual debates have been noticed. The present paper builds upon the basic aspects previously presented, and an attempt is made to zoom in on the updated information about *Artificial-Intelligence* (AI) disrupting progress and three pacing technologies, namely, digital cognitive systems, chatbots, and digital platforms.

In the first part of the paper, the basic aspects concerning automation, digital wellness, human resilience, and various forms of collaboration are reviewed. Several traditional and new applications of automation and AI-based tools and systems in both professional and personal life of the people are described. For example, creating the premises for a *digital proximity* and access to *GLAM* (*galleries, libraries, archives, museums*) with a view to improving the knowledge base and quality of the cultural life of the human is presented and illustrated by an application in the Library of the Romanian Academy. The original Fitts' *MABA-MABA* (*Men Are Better At-Machines Are Better At*) list, and its

recently updated version are discussed, and the early far looking views of several influential personalities such as Douglas Engelbert, Joseph Carl Robnett Licklider, Peter Ducker, Umberto Eco, and Herbert Simon about human-technology interaction and influences are reminded. A particular attention is paid to the *mutualistic* synergy of humans and digital artifacts and the original *declarative model of the experienced decision-maker* as an early anticipatory version of the current digital clones of human actants is evoked.

The second part of the paper addresses the recent developments of AI-based tools and systems and their deployment that are intended to improve the human physical wellness and make the work easier, more comfortable and even pleasant. A particular emphasis is put on the technology developments and business models stimulated by the constraints caused by the recent pandemic. The new attempts and results meant to automate human intellectual functions such as the creation of AGI (*Artificial General Intelligence*) are reviewed together with the revolutionary results of the very innovative technology giants such as *Deep Mind* and *OpenAI*. The early debates on automating human's intellectual functions and the corresponding consequences on people are illustrated by the opposed views of Hubert Lederer Dreyfuss, a philosopher, and Ray Kurzweil, a computer scientist and futurist. The presentation continues with the rather consonant, not too optimistic, evaluations and predictions of Stephan Hawking, Elon Musk, Bill Gates, Steve Wozniak, Ian Hogarth, and Noah Harari. The section concludes with a presentation of several current initiatives and efforts made with the view to ensure observing the ethic requirements in the development and deployment of the new digital artifacts.

The third part of the paper surveys several recent developments meant to make the life of the people more comfortable and the collaboration smoother and more effective. Three particular technology domains are discussed as: a) digital cognitive systems within a *service-oriented architecture* proposed by Jim Spohrer of IBM, b) *chatbots* and the current "battle of wordsmiths" of the emergent or well-established competitor firms, and c) the widespread of platform-based workstyle.

The concluding part of the paper is concerned with the con-

cept of *Digital Humanism* and associated works and events. The section starts by presenting several identified undesirable evolutions of the technologies and the associated business models. Then it surveys the early and rather surprising views of the Sorbonne professor Milad Doueihi on the "quatrième *humanisme numérique*", followed by the pragmatic and business-oriented manifesto of Gartner, the influential work of the German philosopher Julian Nida Rümelin and his colleague Nathalie Weidenfeld, and the rather recent *Digihum (Digital Humanism Initiative), Vienna Manifesto,* and the series of activities at T.U. Vienna that are only a few significant milestones in an ever growing movement aiming at defining and creating the premises for a set of recommendations and actions meant to compensate the downside of technology advances.

Keywords: chatbot, cognitive teams, digital humanism, platform-supported work, virtual exhibition.

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Should Doctors Feel Threatened by Artificial Intelligence? What to Expect from AI in the Medical Field in the Future?

Invited paper

Adrian Iftene

Abstract

This paper briefly presents the recent evolution of artificial intelligence, showing how it can be successfully used in several fields, including the medical field. In the medical field, there are already many areas where digitization and artificial intelligence are successfully used and we will point them out during this paper. In addition, we will try to answer two questions: (1) *Will artificial intelligence replace doctors in the not-too-distant future?* (2) *How far will it go with its use in the medical act?*

Keywords: artificial intelligence, robots, chatbots, personalized medicine.

1 Introduction

We are at the stage where artificial intelligence is starting to help us in everything we do on a daily basis. From unlocking the phone based on fingerprint or face recognition, to facilitating and suggesting how to search on Google or how to write correctly in your own language or in another language, to assisting doctors in diagnosing and predicting the best treatment. The accelerated evolution of digitization in all fields and the evolution of techniques based on artificial intelligence have made all these things possible. In this context, where everything

happens at a very high speed, we obviously ask ourselves the question: *How far will the use of artificial intelligence in everything we do go? Will they reach the stage where doctors will be replaced by intelligent agents that have artificial intelligence behind them?*

2 Where do we meet Artificial Intelligence?

John McCarthy came up with the following definition in 2007 [1] for artificial intelligence "*It is the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable.*"

The imitation of humans has appeared since antiquity when human behavior was imitated by means of statues. Later, mechanical or steam machines were used to imitate people or animals. It was only in 1950 that the first important step in this field was achieved when the mathematician Alan Turing published the book [2], which contained the well-known Turing Test. The Turing test, originally called the imitation game, is a test of a machine's ability to display intelligent behavior equivalent to or indistinguishable from that of a human.

Robots: We have robots like washing machines that help us wash clothes with optimal consumption of water, detergent, and energy. We can remotely start smart vacuum cleaners that are able to scan the space in which they move and that realize the fact that they run out of battery and go to the place where they are powered. We have lawnmowers, that move in an outdoor space and keep the grass at the set size. 750,000 Amazon robots go through huge warehouses [3], pick up racks of products, and take them to human processors who pack them and deliver them to customers with the help of drones. In medicine, robots can play different roles: (1) *passive role*, when the role of the robot is limited in scope, or its involvement is largely low-risk (CT

scan, Cyberknife[1], Aesop[2]), (2) *restricted role* when the robot is responsible for more invasive tasks with higher risk, but is still restricted from essential portions of the procedure (Robodoc[3], Acrobot[4], Neuromate[5]), and (3) *active role* when the robot is intimately involved in the procedure and carries high responsibility and risk (DaVinci[6], manual instruments) (see Figure 1[7]).

Figure 1. Da Vinci Robotic-Assisted Surgery[7]

Chatbots: They help us navigate through the multitude of news (like NBC Politics[8] from Facebook). Enter Roof Ai[9] is a chatbot that helps real-estate marketers automate interaction with their clients. Casper[10] is a conversational agent who aims to give insomniacs someone to talk to while the rest of the people are sleeping. ChatGPT[11] is a natural language processing tool that allows us to have human-like con-

[1]https://cyberknife.com/
[2]https://openmedscience.com/tag/aesop-systems/
[3]http://www.biomedhealthtech.com/robodoc.html
[4]https://acrome.net/product/acrobot
[5]https://www.renishaw.com/en/neuromate-robotic-system-for-stereotactic-neurosurgery–10712
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[11]https://chat.openai.com/

versations and more. It can answer questions and help us with tasks like writing emails, essays, and coding. In medicine, we have companion chatbots for Alzheimer's patients or for those with dementia (Endurance[12]) (see Figure 2[13]).

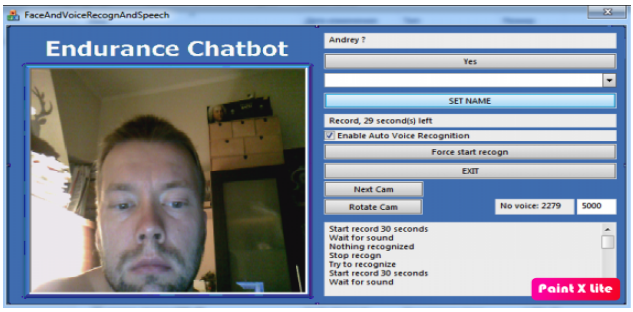

Figure 2. Endurance Chatbot Platform[13]

Education: generating questions for student evaluation is a common practice that helps teachers in the evaluation process [4], Japan is among the first countries to develop such systems with the help of techniques found in question-answer systems [5]. In the medical field, we have applications based on mixed reality that take advantage of the emergence of complex 3D models that can be controlled with the help of gestures or voice. These allow students to have their own CT scan at home and to learn without being forced to be mandatory in the University or hospital laboratories (see Figure 3[14]).

Text processing: it is a field in which artificial intelligence has made many contributions lately [6]. From simple tasks such as the identification of name-type entities [7] to the identification of morphological parts and syntactic processing of the text, to complex tasks based on text understanding [8] and text generation. In hospitals, where often

[12]https://endurancelasers.com/talk-to-endurance-chatbot/

[13]https://roboticsandautomationnews.com/2016/12/10/endurance-robots-launches-open-source-chatbot-platform/9043/

[14]https://www.youtube.com/watch?v=zmdRe_6lqtI

Figure 3. Mixed Reality for Medical Education[14]

the lack of staff causes those who work to be overworked, the possibility of automatic generation of observation sheets is of great help. Using speech-to-text transformation supplemented by NLP techniques greatly reduces the time required for these repetitive activities [9].

Image processing: Automatic processing of images with all that entails object identification, clustering, segmentation, up to the identification of anomalies in images and video. We already have many applications that use these techniques: unlocking phones is done on the basis of fingerprints or facial recognition, in airports we identify people being followed or with suspicious behavior, autonomous driving of cars will appear as soon as possible, etc. In the medical field, we can take into account the identification of tumors, diseases that can be identified by X-ray analysis (such as pneumonia or tuberculosis [10]), or MRIs and CT scans (such as Alzheimer's [11] or atrial fibrillation [12]).

In Fig. 4, we can see a comparison between a healthy brain and Alzheimer's brain[15].

[15]https://www.mayoclinic.org/diseases-conditions/alzheimers-disease/symptoms-causes/syc-20350447

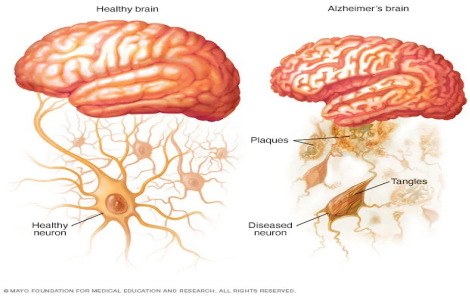

Figure 4. Alzheimer Disease[14]

3 Areas where AI has begun to Surpass Humans

There are many areas where AI has started to achieve better results than humans. This is due to the fact that these solutions usually have behind them (1) huge resources (whether it is textual resources, whether it is images, whether structured or unstructured databases), (2) computing power (supercomputers, with powerful processors, RAM memory, and video processors that process in seconds hundreds of megabytes of images and video and even Cloud solutions from the big companies Google, Amazon, Microsoft, IBM). Let's just think about the fact that image processing algorithms end up working at the pixel level, and for each pixel, we have $256 \times 256 \times 256$ possible colors. It is clear that many possible variants can be obtained, and the human eye cannot distinguish between close values. When an image consists of tens and hundreds of thousands of pixels and even millions, things become even more complex. The role of AI-based applications has evolved a lot, they end up playing chess[16] and Go[17] better than world cham-

[16]https://edition.cnn.com/videos/business/2022/05/11/ibm-deep-blue-computer-beats-garry-kasparov-chess-champion-1997-vault-jg-orig.cnn

[17]https://www.scientificamerican.com/article/ais-victories-in-go-inspire-better-human-game-playing

pions, painting like Rembrandt[18], composing music according to user preferences [13], and writing poems on proposed themes [14]. What's more interesting is the fact that they started writing code and being reliable companions for experienced programmers both in writing functional code and test code. Experiments carried out since the beginning of the year have shown that Github Copilot[19] increases the performance of experienced programmers by up to 30%-40%. The problem occurs with inexperienced programmers who still do not understand the quality of the solutions offered and who do not differentiate between good and bad solutions.

AI can operate with expert-level accuracy in the medical domain [15]: (1) IBM's Watson diagnoses heart disease better than cardiologists, (2) Chatbots provide medical advice for the UK's National Health Service instead of nurses working 24 hours a day and without getting tired, (3) Smartphone apps that rely on increasingly advanced sensors detect skin cancer with expert accuracy, (4) algorithms identify eye diseases as well as medical specialists. It is estimated that medical AI will penetrate 90% hospitals and replace up to 80% of what doctors do today. But for that to happen, the healthcare system will need to overcome patient distrust of AI. Other areas where AI achieves better results than doctors in the medical field are presented below.

Image processing: A first sign of the power of AI in image processing comes from the competition that involves recognizing in an image if we have a dog or a cat. If humans obtain results around 90%, the AI algorithms have exceeded this value and reach around 97-98% [16, 17]. Google says its AI can spot lung cancer a year before doctors [18] and AI is better at diagnosing skin cancer than doctors [19].

ChatGPT outperforms doctors on patient questions: According to the study [20], ChatGPT responses scored a 4 for quality and a 4.67 for empathy, while physician responses scored a 3.33 for quality and 2.33 for empathy. Overall, ChatGPT had 3.6 times more

[18]https://www.discovermagazine.com/technology/how-to-paint-like-rembrandt-according-to-artificial-intelligence

[19]https://github.com/features/copilot

good responses and 9.8 times more empathic responses than doctors.

Accuracy of medical diagnosis: in paper [21], the authors show that the accuracy of medical diagnosis can be improved with causal machine learning. While the associative algorithm achieves an accuracy placing in the top 48% of the doctors involved in the experiment, their algorithm is placed in the top 25% of the doctors, achieving expert-type clinical accuracy.

4 What will the Future Bring us?

The main problems related to the use of AI in the medical field are related to the trust that doctors have in AI-based solutions. The fact that the results are not explained and the behavior is of the black box type (we see the data that enters the algorithm, and we see the results obtained by the algorithm, but we do not understand the motivation behind these decisions), makes the adoption of these techniques slow and durational.

It is clear that AI helps doctors to provide better diagnoses [22] and that they can assist them in all their daily activities, but at the moment this intelligent companion is viewed with distrust and even with the fear that at some point they will take over their tasks. For the moment, AI is a complementary element that the doctor uses, and the patients' need for human interaction, compassion, and understanding will keep him in this position for a long time to come [23]. But we can anticipate that at some point patients will naturally interact with computers and want that trust in them as the primary source of medical guidance.

Explainability and **interpretability** of the results can help to understand them and increase the confidence of doctors and patients in them. OmniXAI[20] library is leveraged, offering an accessible interface and a diverse array of explainability techniques, including 'GradCAM', 'LayerCAM', 'LIME', 'IG', and 'SmoothGrad'. With the help of these techniques, the explanations can be displayed directly on the image

[20]https://github.com/sales force/OmniXAI

samples [24].

It is hoped that **Personalized Medicine** will revolutionize the medical field and allow us to create specific medicines for each patient and to treat them as best as possible, taking into account their profile [25]. Also, the treatment will be adapted according to its evolution, thus optimizing the treatment and recovery process, as well as the costs of medicines and hospitalization.

Modern technologies will change the classic way in which operations will be performed on patients [26]. Augmented reality will give doctors superpowers, through which they will be able to see through the patient they are operating on as if they had the power of X-rays.

5 Conclusion

Artificial intelligence has started to be more and more present in our lives, but also in the lives of doctors. The advantages of using it are immense, making our lives easier, increasing our efficiency, and helping us in many of our daily activities.

We are still faced with the mistrust of those who call on it, and this must simulate us to come up with detailed explanations related to the answers provided by it and the motivation that led to these answers. We anticipate that this will be a direction where those working in AI will invest time and resources in the next period.

Anyway, after we pass this step of trust in AI, we believe that AI will come to help doctors in all activities. There will probably be activities that will be carried out almost entirely by AI (such as X-ray analysis), there will be activities where AI will collaborate with the doctor to find the best solutions (such as operations with the help of mixed realities) and activities that will remain to be carried out only by doctors (such as discussions with patients, their encouragement and advice).

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P Systems with Reactive Membranes

Invited paper

Sergiu Ivanov

Abstract

Membranes are one of the key concepts in P systems and membrane computing, and a lot of research focuses on their properties and possible extensions: membrane division, membrane dissolution, mobile membranes, etc. In this work, we explore the possibility of using membranes for thinking about the emergence of milieu separations at the origins of life. We propose a new variant of P systems with reactive membranes, in which every symbol is initially surrounded by an elementary membrane, and in which membranes can non-deterministically merge and split, leading to the formation of bigger and more complicated membranes. We show that such non-deterministic splitting and merging does not seem to radically affect the computational power: P systems with reactive membranes and non-cooperative rules generate at least all semilinear languages, and cooperative rules allow for simulating partially blind register machines. We briefly discuss using P systems with reactive membranes for illustrating the emergence of autocatalytic cycles, but actual constructions are left for future work.

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Guaranteed Functioning of Cyber-Physical Systems. Models, Methods, Digital Twins

Invited paper

Nataliya D. Pankratova

Abstract

Cyber-physical systems (CPS) are distributed systems with a deep interconnection between their physical and computational elements. The "brain" of the system includes billions of nodes in the form of AI and other technologies. It receives data from sensors in the real world, analyzes this data, and uses it to further control physical elements. The guaranteed functioning of CPS is based on the general problem minimization of multi-factor risks, the margin of permissible risk, the forecast of the destabilizing dynamics of risk factors, principles, hypotheses, and axioms that are directly related to the analysis of abnormal situations, accidents, and disasters. The key idea of the strategy is based on the main principle: to provide timely and reliable detection and estimation of risk factors, prediction of their development during a certain period of operation, and timely identification and elimination of the causes of abnormal situations before failures and other undesirable consequences occur and prevention of the transition from normal to an abnormal mode [1,2]. The fundamentally important peculiarities are the following: sets of risk factors and sets of situations are largely unlimited; a set of risk situations is in principle not a complete group of random events; a threshold restriction of time for decision forming is a top priority; the problem is not completely formalized; indicators of a multifactor risk estimation are not determined; criteria of a multipurpose risk minimization are not determined. The communication with computational systems and different types of sensors is implemented

online in real-time. Joint actions of CPS components determine the properties and special features of the mode of functioning of a complex system at any moment of time. A case of the proposed model implementation is given as an example of a real complex technical system.

To ensure the reliable operation of the CPS, a digital twin is created, which accompanies the operation of the CPS throughout its life cycle [3]. When adopting a control strategy, the digital twin allows for adequate displaying of the dynamics of the physical process, predicting the behavior, detecting system malfunctions, finding modifications in the structure of the physical process by observable effects, and ensuring efficient and uninterrupted operation of CPS. Mathematical models of digital twin creation are proposed [4].

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Data-driven decision support in complex situations-IRIS Integrated Reachback Information System:

Case Study: Data-driven Decision Support and Sector-based Optimization with the management cockpit IDEA4C

IDEA4C – Model Diagnosis, Complex Analysis, Socio-Economic Impacts and Future Operations using special Integrated Assessment Scenarios to optimize a Systemic Risk Analysis

Invited paper

Stefan Wolfgang Pickl

Abstract

The current situation in the context of COVID-19 faced both the decision-makers in politics in particular as well as the players in the logistics industry in general a multitude of complex challenges. The supply chains considered currently need special attention to be optimized on complex disruptions that affect the general security of supply.

As part of the research project "COVID-19 – Future Operations" an interdisciplinary consortium develops a trend-setting interactive visualization tool and management cockpit to support decision makers politics, to adapt and to explore different strategies. This talk gives an overview on that project. Furthermore

it presents the special sector-based approach IDEA4C as part of the IRIS project:

I *– Identification of critical regions, sectors and coupling principles*

Cost-Benefit Analysis for critical sectors

D *– Data-driven constraint optimization*

Coupled Sector-based Models

E *– Exploratory Strategies/ Recognition of critical pathways and sectors*

Characterization of Pathways

A *– Adaptation and Quantifying Analysis*

Coordination of Strategies

This 4C-approach describes a new integrated modelling suite for developing and assessing relief distribution strategies to support quarantined areas during a pandemic situation, based on the latest developments observed in the COVID-19 outbreak.

This **hybrid optimization framework** as example for IRIS has been conceptualized and is currently being developed with and for experts in the field of disaster and emergency management, in order to tackle the real issues arising during such this crisis.

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Infogravity: How the Universe's Evolutionary Information Possibly Explains Emergent Quantum Gravity and Fabric of Space-Time

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Abstract

This paper presents a coherent framework for the nature of the Fabric of Space-Time as Emergent Quantum Gravity under the hypothesis that the Universe represents a complex distributed and asynchronous quantum deep Boltzmann machine with recurrent multilayered neural networks in the proposed model of the Universe as a Quantum Computer model (***the UQC model***). For this purpose, new postulates of the proposed UQC model are formulated based on known scientific facts and theories from computer science and theoretical physics.

Keywords: Fabric of Space-Time, Dual nature of Information in the Universe, Evolutionary Information, Plirophoria, Deep Boltzmann Machine, Emergent Quantum Gravity by Natural Kinds.

1 Introduction: Why Computer Science Cosmology Model?

Presented in this paper approach follows from the main assumption of the ontological equivalence of the Universe's Information/Matter/Energy and the two basic concepts proposed in [2, 3]. Firstly, [2], the definition of the Universe's Information by natural kinds is based on the hypothesis of the Dual nature of Information in the Universe – the Universe's Plirophoria as all evolutionary information ever created,

from one side, and the Universe's Information embedded by Natural kinds in its baryonic matter at any moment of its evolution. Secondly, [3], the proposed model of the dynamical Universe is a Quantum Computer as a complex distributed and asynchronous quantum Boltzmann machine with recurrent multilayered neural networks with two types of quantum calculations by natural kinds. On one side, the evolution of complexity of the baryonic matter (***baryoholons***, [3]) serves as building blocks of complex systems within the Universe's Phenomenon of Life, and on the other side, the evolution of different kinds of complex objects of life-forms (***cyberholons***, [3]) emerges within their hosting galaxies baryoholons.

For the sake of argumentation and clarity of this paper by cybernetic sciences and cybernetic systems, we will further name any domain of modern science (together with complex objects) that roots from the science of cybernetics proposed by Norbert Wiener in [1]. Namely, applied and theoretical computer science, the theory of complex systems, artificial intelligence, the theory of neural networks, systems of virtual reality, and this list is not complete.

The scientific paradigm that explains modern cosmology and the understanding of how reality works from the microscopic level up to clusters of galaxies relies almost entirely on the physical properties of objects and phenomena that occur. In that sense, the state of the art in the science of physics plays a crucial role in guiding further scientific progress. The most successful three theories in physics that are the pillars and driving forces of this process of scientific exploration of reality are namely the Theory of Relativity, the Standard Model of Particle Physics, and Quantum Mechanics.

Nevertheless, we cannot say that all knowledge delivered by these theories defines reality. Rather, the physical theories define a model that approximates reality in a testable fashion. Moreover, due to overwhelming credibility in science, the basic principles proposed by physics become postulates for other sciences that describe the real world. For example, the postulation of matter and energy as the fundamental building blocks of reality at all levels of the Universe. From that fol-

lows that the concept of information in the Universe represents just an artifact of interactions or transitions between matter and energy. From this postulate, also arises the reductionist philosophical stance of modern physics, which claims that all properties of any complex physical system can be reduced to the properties of its components.

But why the computer science and other sciences of Cybernetics that have proven to be incontestable in building models of reality cannot join the mentioned three theories as fundamental pillars of the modern scientific paradigm? As an additional argument for that question, one can say that the main state-of-the-art results of modern physics cannot be achieved without the use of cybernetic sciences. However, here we can note that the main difference between cybernetic sciences and modern physics is that the former treats the concept of information with the same degree of fundamentality as matter and energy. Following that, all cybernetic sciences possess a firmly postulated philosophical anti-reductionist stance that implies the emergence of new properties of a system that cannot be reduced to the properties of its parts.

This work represents one in a series of published papers aimed at postulating a model of the dynamic Universe that functions the same as the real world around us. For the sake of the veridicality of this model, some of the needed principles of the model's functioning will be postulated and some concepts will be defined. Some of them do not coincide with the definitions and postulates of physics, just as the main data structures and rules in constructing pilot training simulating stations do not correspond to those known in the physics of avionics. Nevertheless, it is important to note that such pilot stations are used to train thousands of pilots every day worldwide with systems of virtual and augmented reality, giving them a real feeling that they are acting in reality. The proposed model aims to deliver a new perspective for theoretical physicists who struggle to overcome some mysteries of the modern scientific paradigm. This paper will attempt to deliver an answer to one of the fundamental problems of modern physics – the problem of emergent quantum gravity that can shed light on the nature of the fabric of space-time. To do so, we will use the concepts and

postulates of the Universe as a Quantum Computer (or for short – the **UQC** model) presented in [2] and [3].

2 The Problem of Emerging Quantum Gravity

The proposed in [3] UQC model of the Universe possesses the potential to answer the most stringent paradoxes of the Universe's cosmology. In this paper, we will show that such a model permits explanations for emergent quantum gravity (or EQG), dark matter (or DM), and dark energy (or DE) based on the formulated properties and postulates. A brief introduction to the three problems follows. First, gravity is a cosmic force of unknown nature, very precisely formulated by Isaac Newton that still guides cosmic missions with increasing precision. In addition, the gravitational postulates and equations of Einstein's Theory of Relativity have answered the main paradoxes of cosmology in the 20th century. Nevertheless, no successfully formulated theory explains how gravity acts and emerges at the microscopic, quantum level as well as at macroscopic level. Second, the paradox of the accelerated expansion of the Universe is observed as repulsing galaxies from each other, despite gravity attracting celestial bodies. To explain the Universe's expansion, another repulsive energy in the Universe, named "dark energy", is also required. Third, astronomers have discovered that stars at the edge of galaxies and stars close to the center rotate around the galaxies' center at the same speed, which contradicts the amount of visible matter in a given galaxy. This can be explained only by additional gravity, attributed to "dark matter", which necessitates the presence of at least five times more dark matter than there is visible baryonic matter in the Universe.

Dutch theoretical physicist E. P. Verlinde [4, 5] has proposed the state-of-the-art theory of emergent quantum gravity that attempts to answer the above-mentioned three problems. He advances the idea of the entropic origin of gravity by analogy with the entropic nature of temperature or pressure that emerges from the collective behavior of atoms and molecules in a given volume. For example, the tem-

perature of a hot cup of coffee represents an emergent thermodynamic macroscopic phenomenon based on microscopic vibrations of atoms and molecules within a limited cup's volume. E. Verlinde employs the entangled quantum information existing between interacting molecules as a driving force in the phenomenon of emergent quantum gravity. Nevertheless, the proposed hypothesis is not rooted in known physical facts and principles. By contrast, the proposed in [3] UQC model together with new concepts and postulates formulated below and based on Landauer's principle for irreversible calculations, can provide possible answers to the above-mentioned problems.

3 Possible Solution for EQG, DE, and DM based on the UQC model

For a clearer understanding of the proposed approach to emergent quantum gravity, several main points of the UQC model of the Universe, as proposed in [2, 3], are outlined below. To avoid mixing notations, we will use the same numbering as in [2, 3] when referring to the definitions and postulates of the model. For new ones introduced in this work, an additional prefix 'G' will be added. In addition to the proposed in [3] UQC model, we will mention recently discovered scientific facts that allow us to enhance the proposed model of the Universe as a quantum deep Boltzmann machine with topologically braided quantum neural networks.

Two independent research groups have reported the successful creation of strange 2D particle-like objects called non-abelian anyons [6, 7]. These 2D quasiparticles can be braided in 3D and can be moved around one another, retaining memory of past events. This discovery can assist scientists in constructing a new type of topological quantum computers that are resistant to calculation errors. With that said, we are prepared to formulate new postulates and definitions for the UQC model, but not before a quick refresh of the main principles of the UQC model based on existing scientific facts.

- The Universe's baryonic matter consists of 10**80 atoms formed during the baryosynthesis epoch after the Big Bang and that will exist for the next trillions of years;
- The evolution of the Universe's baryonic matter nests mainly within galaxies and clusters of galaxies;
- The Universe's matter forms a fractal structured holarchy of celestial objects that resembles the following levels of a hierarchy of realms – a realm of galaxies clusters and voids; a realm of galaxies; a realm of stars systems, nebulas, neutron stars, and black holes; a realm of planets with their satellites, planetary discs, meteorites, and comets;

  All above mentioned Universe's realms of holons are responsible for the evolution of baryonic matter in the Universe towards increasing complexity of the newly formed chemical atoms and in the UQC model have a nickname as "***baryoholons***".
- The formation of the Universe's complex matter takes place on Earth-like exoplanets and is a subject of the evolution of planetary conditions towards the emergence of the phenomenon of Life; in the UQC model, the phenomenon of Life possesses the status of "Law of Nature" and acts in all planetary realms towards the formation of complex life forms;

  The above-mentioned realm of planets of the UQC model hosts for some period from one to a few billion years the phenomenon of the ongoing evolution of complex life forms, that in the UQC model is nicknamed "***cyberholons***", as their evolution is subject of feedback control, as N. Wiener pointed in [1].
- The UQC model resembles the Universe as a complex distributed and asynchronous quantum deep Boltzmann machine with recurrent multilayered topologically braided neural networks; each from the existing 10**80 Universe's atoms in the UQC model possesses a dual nature. On one side, as an atom of a chemical element – a microscopic building block on the quantum level of a complex physical object due to the perpetual phenomenon

of quantum decoherence of quantum states of the object. On the other side, as an input-output visible node of a distributed self-assembling quantum Boltzmann machine that resembles that given complex object, an organic molecule, for example.

- The Universe's evolutionary information named in [2] the Plirophoria, in the UQC model, resides in the hidden nodes of the recurrent multilayered topologically braided neural networks entangled with a given atom. Each time, when the wave function of a given atom collapses and changes its quantum state, a new hidden node of Plirophoria emerges with a mass calculated by Landauer's limit and with volume given by the Plank length;
- - The above-mentioned hidden nodes of neural networks of the Boltzmann machine in [3] are named ***pliroknots*** being linked with ***plirobrades***, as used in the braid theory. We will use both denominations for the sake of the completeness of the UQC model.

For the UQC model, to meet the requirements to be able to answer the three main questions, the following postulates are needed.

Postulate G_01. The 3D real world and the quantum realm represent a superposition unity of both realms simultaneously. Each real classical object in a 3D Universe can be zoomed down to its quantum components as molecules, atoms, and subatomic particles down to the Planck scale. In its turn, each quantum subatomic particle can be zoomed up towards the minimal classical objects that contain a given quantum object. The zooming-up process can be prolonged up to stellar, galactic, or even higher realm of holarchy.

Postulate G_01A. To admit existence in UQC-model the postulated above superposition of quantum realm and of 3D reality the following important two assumptions have to be formulated. First, each from three Euclidian coordinates (X,Y,Z) takes complex numbers, not real numbers such as $x = a + i * b$; $y = a + j * b$; $z = a + k * b$; where i, j and k are the imaginary numbers of quaternionic complex representation with known properties.

Postulate G_01B. (Emergent Plirophoria): Each step of the calculation process in the UQC model takes place simultaneously in 3D space as the evolution of a classical object and in the quantum realm as the creation of new quanta of space, serving as new storage for remembering the evolutionary information of the previous quantum state that recently collapsed. These quanta of space that we define as "infograviton", possess mass in correspondence with Landauer's principle, and represent a volume in accordance with Planck length.

Postulate G_01C. Each atom in the UQC model possesses its own anchored and entangled evolutionary information (Plirophoria). The atom's Plirophoria possesses the same 3D volume and mass calculated by Landauer's principle as its constituent subatomic particles, such as quarks and gluons.

Postulate G_02: The atom's Plirophoria can detach from the atom's nucleus only under the condition that the atom ceases to exist due to nuclear reactions. When this occurs, the detached atom's Plirophoria embarks on its journey, pushed by the detached Plirophoria of other vanished atoms.

Postulate G_03: Atoms represent the elementary Pliroheads of a distributed self-assembling Boltzmann quantum computer in a given place of a 3D classical object during its evolution. The Plirophoria of that specific classical object represents the quantum entanglement of all of the object's atom's Plirophoria. The Plirophoria of a complex object becomes detached when the classical object ceases to exist due to environmental or other conditions.

Postulate G_04: The emerged Plirophoria during the evolution of a classical object, after its "death" and dissipation into its constituent atoms, retains a shape resembling the 3D form and volume of the evolved complex object but detaches from its constituent atoms and begins its journey within the surrounding space.
To clarify the above postulate, one can imagine the evolution of a living organism. Its Plirophoria emerges from the Plirophoria of its constituent cells, which, in turn, resemble and become entangled with

the Plirophoria of all constituent atoms. When the organism ceases to exist, its Plirophoria retains the physical volume occupied in 3D space by the living organism and detaches from it.

Postulate G_05: The calculation process, as the decoherence of quantum states of quantum systems, has two effects. On one side, it embeds the new states of decohered quantum information into the object's classical matter, such as atoms, molecules, living cells, or stellar systems. On the other side, due to calculation, the previous states of quantum information of the system are memorized as Plirophoria for each calculating step, for each level of complexity, down to any single atom.

Postulate G_05A: The decoherence of the quantum states of the Universe's atoms, as a calculating process in the UQC model, represents an asynchronous process not driven by a central clock system but rather by its own clock and time.

Postulate G_06: During the UQC calculations, which govern a complex object's system, the decoherence of quantum states processes is imprinted in the complex object's emergent Plirophoria, resulting in topologically shaped quantum information for each atom involved in these changes. Each change generates a quantum of Plirophoria with a specific mass calculated by Landauer's principle, specific to that given element's atom. With that specific quantum of new mass, a new volume of space and a new "mass momentum" specific to the involved element's atom is created.

Postulate G_06A: The fabric of space-time emerges as a new quantum of topologically braided elementary Plirophoria when each quantum state of a given atom collapses. Each such quantum of the fabric of space-time possesses its own mass due to Landauer's principle, its own volume characteristic of a type of the element, and its own "mass momentum".

Postulate G_07. All newly created pliroknots become entangled with each other via plirobraids and represent the entangled fabric of space-time.

Postulate G_08. Gravity Momentum (***or Gravity Spin***) of each pliroknot remains entangled and in a state of superposition with all neighbor ***pliroknots***, including the one entangled with baryonic matter' ***plirohead [3]***.

Postulate G_09. Entangled pliroknots of the fabric of space-time remain entangled with all baryoholons and cyberholons in the Universe simultaneously with Additive Gravity entanglement property towards any holon in the Universe.

Postulate G_10. The property of Additivity of Entangled Gravity manifests as follows:

- gravity adds the mass spin-momentum of all the pliroknots all the path down to the targeted Universe's holon;
- this process takes place in superposition towards all possible trajectories that begin from a given plirohead;
- the surface of a given holon plirohead entangled with a target baryo- or cyberholon plays the role of the integral surface that adds on the gravity of all elementary pliroheads entangled with the target's holon pliroheads.

Postulate G_11. The entangled plirophoria of a given holon generates a pooling force equal to all flux generated by plirophoria's pliroheads surface and by that accelerating it towards all neighborhood Universe's holons.

4 Summary of the mechanism of emergent Plirophoria

As postulated in [3], there are two independent branches in the UQC model self-calculation process. The first one controls the evolution of the baryoholons, which, in turn, produce new types of all known elements of baryonic matter, such as helium, carbon, metals, and other

chemical elements. However, this branch of calculation has a distributed endpoint – the local black holes. These black holes concentrate elementary baryonic matter within their inner singularities, releasing the Plirophoria of the falling baryonic matter out of the edge of the black hole's event horizon. This Plirophoria becomes part of the Quantum Evolutionary Information 'wind' oriented towards the outskirts of hosting galaxies. This Plirophoria's 'wind' represents pure dark energy that pushes galaxies apart.

The second branch of the UQC model calculation process occurs in the realm of cyberholons, formed by the interaction of baryonic matter, including newly created types of baryonic matter. This distributed calculation process is driven by the Phenomenon of Life's algorithm, created under the control of knowledge and rules (laws of nature) emerging within entangled neural topologically braided quantum neural networks of hidden nodes of a local deep Boltzmann's machine.

The second branch is responsible for calculating the evolutionary process of complex cyberholonic systems that can stick to or split from each other to evolve into complex cyberholons, similar to living creatures. Moreover, this branch is responsible for calculating new types of species during the process of evolution of life on a given exoplanet, originating from the realm of cyberolons. However, the calculation process has the same endpoint – the nearest situated black hole. At the event horizon, all baryonic matter falls in, and two types of Plirophoria 'wind' flow outward from the black hole: the Plirophoria of evolved complex cyberholons, following their path within the fabric of spacetime, and the last "state of the art" quantum informational imprint of decohered quantum baryonic matter.

It follows that the fabric of spacetime possesses a dual structure – on one side, very tiny baryonic Plirophoria, and on the other side, rather "heavy and rigid" cyberholonic Plirophoria. The first type of Plirophoria, due to its properties, represents the more fluid part of this 'wind', capable of self-acceleration and passing through the more rigid and complex cyberholonic Plirophoria. From this situation, one can easily differentiate the first type as an accelerated type, representing the

essence of dark energy. The second type flows less fluently through the fabric of spacetime and can easily adhere to the alongside plirophoria of exoplanets or stars, becoming a part of unseen dark matter.

5 Conclusions

The proposed above approach to the emerging quantized entangled fabric of the space-time model follows the same path of thoughts as Erik P. Verlinde does in [9] with one main difference. The UGC model treats the fabric of space-time as an entangled fabric of evolutionary information (plirophoria) braided by calculating processes in any of the distributed elementary processors of the UQM model. For each piece of newly stored plirophoria, the UQC creates a new quantum of the fabric of space-time. Follows, that in the UQC model, not only gravity but the fabric of space-time represents an emergent phenomenon. Time remains embedded in the fabric of space-time as proof of a change in the UQC calculating process of the Universe's evolution in a given volume of matter.

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Enhancing Interaction Design in AI-Powered Systems

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Abstract

In recent years, AI-powered systems have become integral to the healthcare industry. As these systems continue to proliferate, the need for effective and intuitive user interactions becomes increasingly critical. This research paper explores the challenges and opportunities in enhancing interaction design for AI-powered systems in the healthcare industry. The findings of the study underscore the significance of optimizing interaction design in AI systems to seamlessly integrate certain capabilities into doctors' and patients' everyday lives.

Keywords: interaction design, healthcare, human-centered AI, artificial intelligence.

1. Introduction

In the healthcare industry, a good design makes interactions between clinicians and patients effortless. Badly designed products could directly impact patients' lives. It is often the case when poor design could lead to life-threatening medical errors. Additionally, medical errors were reported to be among the leading causes of death in many developed countries. The integration of artificial intelligence (AI) technology in the healthcare industry has transformed the landscape of healthcare delivery. One crucial aspect of this transformation is the role of interaction design in creating user-friendly AI-powered applications and systems for healthcare professionals and patients.

2. Digital Transformation in Healthcare Industry

Digital Healthcare Transformation (DHT) is, as in any industry, a mix of both healthcare automation and digitization. In many countries, even the

most developed ones, DHT is still considered in the early stages, and its benefits are underestimated [1].

3. Health Design Thinking

Human-centered healthcare design addresses the complexity of healthcare systems. AI/ML can be applied in healthcare design in numerous ways: personalized care, predictive analytics, medical imaging, drug discovery, robotics, or virtual assistants.

3.1 Participatory Design

Participatory design is often used in contexts where end-users or stakeholders have unique expertise or perspectives that are important for creating effective and usable products or services. In healthcare, participatory design may involve patients, caregivers, and healthcare providers in the design of medical devices, patient portals, or other health technologies.

Inclusiveness and collaboration are part of participatory design practice. Therefore, "healthcare users – including patients, clinicians, families, and communities – are active participants, not passive subjects to be measured" [2].

3.1.1 Co-Design

Three types of participatory design have been proposed by MIT[1]:

1. User-centered design
2. User-generated design
3. Co-design

Co-design is particularly applicable in the healthcare sector. Co-designing practice plays an important role because it allows participants who are not normally involved in design activities to directly provide user-driven ideas and perspectives to explore problems and possible solutions. The outcome of a co-design session is not intended to be necessarily a market-ready solution.

When we talk about frameworks, one of them refers to four levels of co-design that have been identified and that worked and have been used in

[1] https://d-lab.mit.edu/

the healthcare industry. Based on a study done on autistic adults [3], we can identify 4 stages of the co-design process:

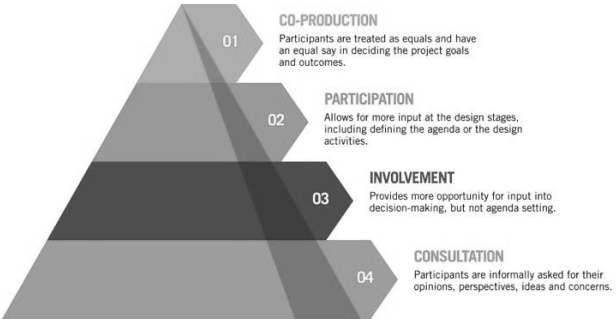

Figure 1. Stages of the co-design process [3]

3.2 Social Determinants

Designing for the healthcare industry also requires an understanding of the social determinants of health, which are the underlying social and economic factors that influence health outcomes. According to a study [4], social determinants can include factors such as socioeconomic status, race, ethnicity, or education level.

4. Data as Design Material

Data has been used in several ways in the design process:

1. Data-inspired design: where decisions are taken based on intuition and personal preferences.
2. Data-informed design: where design decisions are taken based on research activities of all kinds: ethnographic research, user testing, etc.
3. Data-driven design on the other hand will dictate all the design decisions since they are based on data rather than intuition or personal preferences.

5. Making Technology Work for Healthcare

5.1 Human-Centered AI

Understanding the relationship between AI and humans will help us build better AI products. The practice of Human-Centered AI (HCAI) will help

us design "systems that support human self-efficacy, promote creativity, clarify responsibility, and facilitate social participation" [5]. Therefore, building intelligent systems designed with social responsibility in mind would be a priority of HCAI.

5.2 Artificial Intelligence First Healthcare

All the actors in the healthcare industry could gain from the prevalence of AI. Doctors could be notified about abnormalities in medication adherence and treatment decisions and could be augmented with AI algorithms that learn from best care practices.

5.2.1 Medication Management and AI

Non-adherence to medication could lead to "waste of medication, disease progression, reduced functional abilities, a lower quality of life" [8].

According to a recent study [6], multiple AI-assisted technologies are used to increase medication adherence: mobile phone applications, reminder systems, AI for patient empowerment, AI in integrated care, Machine Learning (ML), and big data analytics.

5.2.2 Vocal biomarkers

Voice analysis using artificial intelligence opens new opportunities for healthcare. Certain diseases such as Alzheimer's disease, Parkinson's, multiple sclerosis, or rheumatoid arthritis can alter an individual's voice. In Parkinson's disease, in particular, voice disorders are as high as 89% [7], which will make a good case for using vocal biomarkers. Vocal biomarkers drive a clinical outcome and can be used to monitor and diagnose a disease.

5.2.3 Skin Screening

Teledermatology has evolved to the point where a mobile phone can be used to take pictures of the affected skin and send them to be processed. Early detection is critical in skin cancer treatment. Certain applications such as DermAssist by Google[2], are currently undergoing market testing already. DermAssist provides patients with a list of possible matching

[2] https://health.google/consumers/dermassist/

skin conditions, and helpful information about each and is built using AI technology.

6. Conclusion

This research underscores the critical significance of optimizing interaction design in AI-powered systems to revolutionize patient care, streamline clinical workflows, and drive improved health outcomes. The next steps of the research aim at developing new methods and tools for assisting in the development of AI-based systems with regards to articulating ethical issues in participatory design processes and as part of everyday living; what risks may arise in terms of autonomy and how they may be mitigated, how trust and sense of control can be promoted when integrating AI systems in healthcare environment.

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Integrated e-Infrastructure to support research and educational activities

Petru Bogatencov, Nichita Degteariov

Abstract

In the article, there are described European, regional, and national initiatives in the area of e-Infrastructure resources and services for supporting research and educational activities that are available for R&E institutions of Moldova. There are presented approaches and solutions for the deployment of the national networking and distributed computing infrastructures, specific services for research and education. A concept of multi-zone IaaS cloud infrastructure has been elaborated and implemented that combines the resources of several organizations, aimed at supporting a distributed environment for intensifying the use of e-infrastructure resources and deploying a wide range of services offered to end users.

Keywords: e-infrastructures & services, multi-zone cloud computing infrastructure, tools for supporting scientific applications.

1. Introduction

A significant contribution to the development of e-Infrastructure resources and tools for supporting e-Science and e-Education has been made due to the participation of institutions from Moldova in various European Programmes and projects. This allowed the development, deployment, and provision of a wide range of digital services and access to modern computing resources. These initiatives enabled an expansion of hardware resources and the use of new tools to automate research data management and service delivery.

The introduction of modern architectural solutions, tools, and platforms, as well as the installation of new high-performance computing

resources, have made it possible to extend the use of computing infrastructures. The concept of creating a heterogeneous computing cloud infrastructure IaaS (IaaS - Infrastructure as a Service) has been developed. The implemented IaaS cloud computing infrastructure offers conditions for providing computing and storage resources over a high-speed optical network. The demands for the use of computing infrastructure and services to support the accumulation, storage, and processing of research data are constantly increasing. E-infrastructures are becoming more and more popular and versatile tools to intensify modern science and education activities. End-users are looking for a wide range of services for data management and computing resources for developing and executing complex applications.

2. Computing and Data Infrastructures for use by research and educational communities

In recent two decades, the EU via different projects contributed to the building of the next-generation pan-European and regional networking and computing infrastructures for providing intensive computation and analysis of shared large-scale datasets. The recent regional initiatives pushed to deploy sustainable national Grid and Cloud infrastructures in the Eastern Europe Partnership (EaP) countries and to integrate them into the pan-European and worldwide e-Infrastructures. Moldavian, Armenian, and Georgian computing infrastructures were developing as a part of the Southeast Europe computing initiative. In parallel, National Computing Initiatives (NCI) have been established in EaP countries, which manage the computing resources provided to the national users' communities and integrated into the European and regional computing infrastructures. In addition, NCIs are focusing on forming national users' communities, providing end-user support, analyzing the needs of users, and deploying demanded services for users' communities.

The European Union invests heavily in the development of electronic research infrastructures, based on interconnected supercomputers and HPC clusters, distributed computing Cloud, using open-source software and providing a rich set of user-oriented services. The European Commission has supported the building and integration of electronic research infrastructures comprising computing resources and data

warehouses with large cloud storage capacities and advanced features. In order to maximize the use of such expensive equipment, it was necessary to deploy a high-speed networking environment and integrated set of services that provide flexible and transparent access to the computing and storage resources [1,2].

In 2010, the European Grid Foundation (EGI) was launched. The goal of EGI-InSPIRE project (EU FP7 EGI-InSPIRE project, 2014) was to establish a sustainable European computing infrastructure and provide European scientists and their international partners with sustainable and reliable distributed computing resources that can support their needs for large-scale data analysis and simulations. 51 national and international institutions from Europe and the Asia Pacific region were partners of the project, among them EaP countries organizations from Moldova, Armenia, Belarus, Georgia, and Ukraine. Information about computing facilities in EaP countries is presented in Table 1.

Table 1. Grid and cloud computing facilities in EaP countries (source: EGI-InSPIRE project statistics (2018).

	Total Number of Sites	Physical CPU	Logical CPU	Storage Capacity, TB	Supported VOs
Armenia	8	148	592	27	6
Azerbaijan	3	84	336	72	4
Belarus	6	64	228	28	2
Georgia	2	74	300	28	5
Moldova	3	48	192	11	5
Ukraine	41	938	2372	455	45

Examples of regional initiatives that offered resources for research teams from Moldova are “VRE for regional Interdisciplinary communities

in Southeast Europe and the Eastern Mediterranean (VI-SEEM)" and "National Initiatives for Open Science in Europe" (NI4OS Europe) regional projects. These projects united 15 partners, including from Moldova, each of which provided for the purposes of the projects part of their own resources with the aim to deliver to national R&E communities an integrated Virtual Research Environment, that includes supercomputers, multiprocessor clusters, distributed cloud infrastructures, and advanced storage facilities. The idea of the Virtual Research Environment is to create an integrated environment that serves the needs of a wide set of researchers. The platform is linking compute, data, and visualization resources, as well as services, software, and tools for the various Virtual Research Communities. The innovative potential of such virtual labs makes them interesting for industry, especially for medical research and research related to agriculture and the impact of climate change.

Access to the regional computing resources was organized on the base of Open Calls. Research teams from Moldova actively participated in these calls, and two applications from Moldova were awarded in 2021-2022 and got access to resources of regional computing and storage infrastructures: "Platform for Digitization of Romanian Historical Heritage Printed in the Cyrillic Script" (team leader Dr. Tudor Bumbu, Vladimir Andrunachievici Institute of Mathematics and Computer Science) and "Study of magnetic nanoclusters with d-f metals" (team leader Assoc. Prof., Dr. Yurii Chumakov, the Institute of Applied Physics).

3. Services for regional and national research and educational communities

In 2014, the European Commission initiated a feasibility study with the aim of analyzing the requirements of national research and educational communities in e-Infrastructure resources and services and identifying the most demanded e-Infrastructure services in the EaP region [3]. This analysis was used during the EaPConnect project proposal elaboration. The selected services, recommended for development in EaP countries, enable to support of the needs of researchers, students, educators, and

other user communities both at national and regional levels. The services proposed for implementation are grouped as presented in Fig. 1.

With the support of the EaPConnect project, the following groups of basic e-Infrastructure services were deployed in EaP countries:

1. Connectivity & network management: *eduroam* - wi-fi roaming; *perfSONAR* - PERFormance Service Oriented Network Monitoring Architecture; *Software Defined Networks* - allow users themselves to manage parameters of the owned network infrastructure.
2. Trust & Identity: *Web Single Sign-On* - the federated service available to connect campuses via identity federations; *eduGAIN* - service for organization of inter-federation environments.
3. Specific/thematic: *Open Access initiative* - a value-added service for R&E communities that is dedicated to supporting and promoting open access to electronic publications; *Platforms and tools* for support of Open Science; *Real-time musical collaboration LOLA* (LOw LAtency audio visual streaming system); *Digitization of Cultural Heritage*.
4. Access to *cloud computing and HPC resources*.

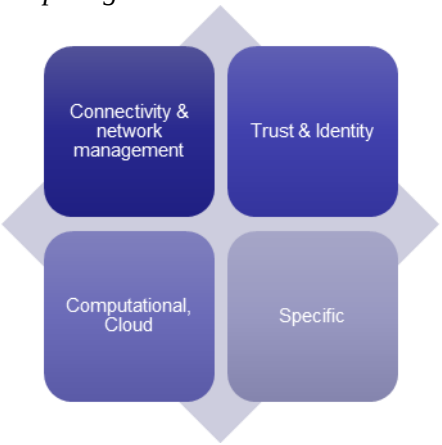

Figure 1. Grouping of the implemented e-Infrastructure services

In 2021, with methodological support of the EaPConnect project and organizational assistance of the Ministry of Education and Research of Moldova, there was organized the Users' Needs Assessment Survey to clarify the needs of the national R&E users' community in e-Infrastructure services offered by the national e-Infrastructures providers. Analysis of

170 responses received identified the following priorities of services take-up in Moldova:

- Need to increase external and internal connectivity (53% of responders);
- eduroam - wi-fi roaming (70% of responders);
- eduGAIN and identity management services (72% of responders);
- Video conferencing (70% of responders);
- Research data virtual archiving service (61% of responders);
- Virtual learning environment services, such as Moodle, integrated with real-time communications (60% of responders);
- Use of Cloud computing and HPC resources (52% of responders).

4. Deployment of the national distributed computing infrastructure

Work on the implementation of distributed computing infrastructure in Moldova started in 2007 when the first Agreement on the creation of the MD-GIRD Joint Research Unit Consortium and accompanying Memorandums of Understanding were signed by seven universities and research institutes of Moldova. Since this time, the works started on the deployment of the national distributed computing infrastructure that included the integration of computing clusters and servers deployed in the main national universities and research institutions. For effective integration of different types of computing resources into the common distributed infrastructure, there was used high-capacity optical communication backbone provided by NREN RENAM [4].

In 2018, the created distributed computing infrastructure was upgraded with modern high-performance servers. This upgrade has opened a new stage in the development of scientific Cloud computing facilities – new resources were allocated for several projects in the field of Machine Learning and Neural Language Processing. Since 2019 the created Cloud infrastructure began to be used for new services – support of on-line lectures organization for universities of Moldova. Although the deployed system had some disadvantages due to the limited number of available resources and lack of a high throughput network interconnection between some nodes and storage elements, the experience gained over the

years and user feedback made it clear the necessity of further development of National Cloud infrastructure [5].

At this time, there was elaborated the concept of implementation of the heterogeneous multi-cloud platform that united computing resources of several data centers deployed in research and educational institutions of Moldova. Since 2020, work has been started on testing different systems of computing resources virtualization and different solutions for creating multi-level data storage systems for large volumes of research data accumulation and archiving for deployment of distributed infrastructure based on the elaborated concept of a multi-cloud platform. The structure of the distributed system based on the implementation of a heterogeneous multi-cloud platform that integrates the available national computing resources was proposed for practical implementation that includes various types of computing environments and specialized subsystems for data storage.

The realized at the first stage distributed computing infrastructure unites four main data centers located in the State University of Moldova (SUM), Vladimir Andrunachievich Institute of Mathematics and Computer Science (VA IMCS), Institute of Emergency Medicine and RENAM Association that are permanently developing. The common computing resources now comprise more than 400 CPU cores, 2 NVIDIA T4 Tensor Core GPU units, and 60 TB of storage resources [6]. The elaborated concept of the creation of the heterogenous computing infrastructure includes multi-zone IaaS Cloud infrastructure (Fig. 2), a pool of virtualized servers that are used for permanent resource allocation to execute production services, multiprocessor clusters, and bare metal serves that are used for running intensive data processing applications. The distributed infrastructure comprises dedicated storage sub-systems for large amounts of data archiving and providing resources for the whole distributed infrastructure data backup. The distributed computing infrastructure supports the adaptive execution framework that can be adapted for the solution of different types of complex applications. The deployed multi-zone IaaS Cloud infrastructure is used for performing intensive scientific calculations, as well as storing and archiving large amounts of research data and results of computational experiments. The research team from SUM developed several applications that require

resources of multiprocessor clusters integrated into the distributed Cloud infrastructure.

Works on the deployment of an updated Scientific multi-zone IaaS Cloud Infrastructure, that is based on OpenStack Ussuri, began in 2021 and are progressing now taking into account the continuation of physical computing resources upgrading by the installation of new servers in all main data centers. As a result, today in the created Cloud Infrastructure in parallel are available and operating previously deployed resources, based on outdated OpenStack versions and updated Cloud platform, where OpenStack version 2023.1 Antelope is deployed, which is currently the most recent stable release that will be actively maintained at least for the upcoming year, offering more features, more processing power, and flexibility of operation [7].

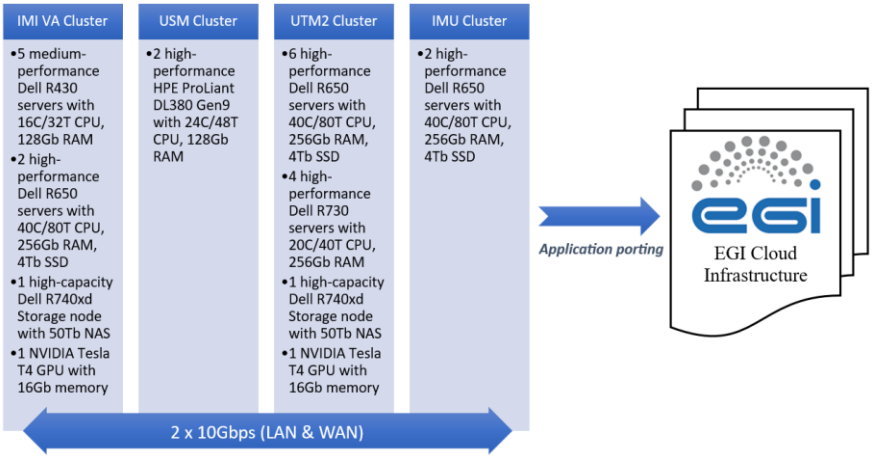

Figure 2. General scheme of the created multi-cloud infrastructure

In the currently distributed cloud understructure, useful and important components are implemented - block storage and Virtual eXtensible Local Area Network (VXLAN) traffic tagging. Block storage allows the creation of volumes for organizing persistent storage. This is a kind of network flash drive that can be mounted to any virtual machine associated with the user's project, unmounted and remounted to another, etc., and most importantly, this type of volume is persistent storage that can be reused when the virtual machines are deleted. Thus, you can easily move data

from one virtual machine to another, or quickly scale up VM performance by creating a virtual machine with larger resources and simply mount volumes to it with all scientific data available for further processing.

VXLAN is an advanced and flexible model of interaction with the network. In the upgraded cloud infrastructure, in addition to the usual "provider network" model, which allocates one real IP address from the pool of provider network addresses to each virtual machine, a self-service network is also available. A self-service network allows each user's project to create its own local network with Internet access via NAT (Network Address Translation). For a self-service network, the user can create a virtual router for his project with its own address space. The external IP address remains assigned to the project and can be reused by other machines within the project.

For effective operation of the upgraded computing infrastructure, a new 10G virtual networking segment was deployed. Now there is being realized the procedure of switching the connection of all servers to Nx10G interfaces [8].

The distributed computing infrastructure now provides the following production services, software platforms, and tools:

Jupyter Notebook - is a web-based interactive computing platform. The notebook combines live code, equations, narrative text, and visualizations. Jupyter Notebook allows users to compile all aspects of a data project in one place making it easier to show the entire process of a project to your intended audience. Through the web-based application, users can create data visualizations and other components of a project to share with others via the platform.

BigBlueButton integrated with Moodle is a multi-purpose built virtual classroom.

TensorFlow 2 - an end-to-end open-source machine learning platform.

Keras: Deep Learning for humans. Keras is a high-level, deep-learning API developed by Google for implementing neural networks. It makes the implementation of neural networks easy and supports multiple backend neural network computations.

Anaconda Distribution: equips individuals to easily search and install thousands of Python/R packages and access a vast library of community content and support.

The Apache Tomcat® software is an open-source implementation of the Java Servlet, JavaServer Pages, Java Expression Language, and Java WebSocket technologies.

Pandas is a fast, powerful, flexible, and easy-to-use open-source data analysis and manipulation tool, built on top of the Python programming language.

Nextcloud is a self-hosted, open-source file-sharing and collaboration platform that allows users to store, access, and share their data from any device or location.

The created computing infrastructure is used for the development and execution of complex scientific applications elaborated by research teams from universities and research institutions, development and operation services for support educational activities, and for hosting basic and specific e-Infrastructure services that are necessary for research data management and access to the e-Infrastructures resources.

5. Conclusion

During the last years, important development of e-Infrastructure in Moldova has been made. Participation in the realization of European and regional e-Infrastructure development projects significantly contributed to the development of high-quality networking infrastructure, national and regional distributed computing resources, deployment of well-developed informational services, and also to providing access to European Research Infrastructures with global impact for research and educational communities in Moldova and EaP region.

The created heterogeneous distributed computing infrastructure in Moldova allowed increasing the effectiveness of scientific and educational activities, including supporting the implementation of the Open Science concept.

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Safety System for Robotic Processes Based on Voice Emotion Recognition

Olesea Borozan

Abstract

This thesis is an innovative approach aimed at improving the safety and efficiency of robotized processes by using the recognition of voice emotions, in order to manage emergencies. The main goal of this thesis is to develop a new safety system that allows identification and influences the functioning of the robotized system (stopping the system or placing it into the enhanced safety regime), depending on the emotional state of its user/human operator. There has been developed the chart classifying the phenomena that may entail emergencies, the human beings' response to such emergencies, and the mathematical model that, being implemented in the architecture of a Neuronal Network, will generate command decisions for the robotized system.

Keywords: vital safety system, robotic processes, emotions, speech processing, exceptional situations, Neural Networks.

1. Introduction

Voice emotions are a way to express the emotional state of an individual (human being, animal, or bird), due to such characteristics of their voice as tonality, rhythm, volume, and other factors. Hence, human beings have the capacity to change their voices, depending on their positive or negative emotional state, fright or fear, while such changes may be perceived and identified by decisional systems that can interfere through the actions, that are specific to the relevant situation and sphere of their activity [1].

Hence, the process of emotions recognition in speech implies the analysis of voice changes, which are caused by emotions, with acoustic analysis, and the determination of characteristics, which must be used in

order to recognize emotions. The number of characteristics that were obtained through acoustic analysis, reaches huge figures (≈ 1000), depending on the number of used acoustic parameters and on the statistical variations of such parameters. However, not all of such characteristics are enough for recognizing the emotions. Moreover, different emotions may affect different voice features. So, this is the reason why there are used methods of characteristics selection, in order to increase the success of emotional recognition and also in order to diminish the scope of work by processing as few characteristics as possible. The method, which is proposed in this thesis [2], ensures a significant reduction of the number of characteristics (about 37 data sets), and, as well, more successful classification, due to using a new statistical method of characteristics selection, which is based on changes in emotions, relying on acoustic characteristics.

The emotional speech analysis is a relevant and well-spread sphere of research. Numerous scientific works have provided significant results when the voice allowed the identification of the physical, mental, and physiological state of human beings [3, 4]. Meanwhile, there are also mentioned the challenges that arise because of age or gender and that need the use of extra technical and technological resources (models, which are based on Artificial Intelligence and e-Learning), which are required for achieving the requested objectives, as a result of emotional speech analysis [5, 6].

It is important that the voice emotions may vary, depending on the speaker's culture and individuality. Besides this, such emotions may be influenced by the context of the talk and by the way such a speaker controls or expresses his emotions. As for the research that have been made within this thesis, the analysis of voice characteristics is used in order to develop the techniques for the emotions recognition or in order to assess the emotional state of a person, based on their voice, or in order to take decisions, depending on the situation and sphere of activity.

2. The way of expressing dangerous situations for human health

The dangerous situations for human health may be classified according to the chart, which is provided in Figure 1.

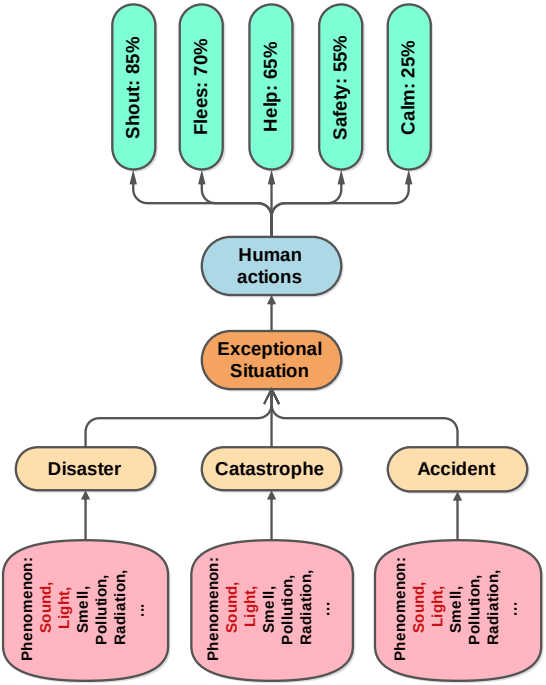

Figure 1. Classification of phenomena and methods of expressing dangerous situations for human health

According to this chart (Figure 1), emergencies may be classified as correlated to the area of their influence, as follows: disaster, catastrophe, or accidents. All of them are manifested through different physical and/or chemical phenomena, which are perceived by human beings and animals, for instance: sound, light, smell, pollution, radiation, and so on.

It is obvious that in emergencies, human beings aim to save their life or health, and so they take certain actions that are manifested through simultaneous and noncontrolled deeds, such as:

- Making sounds: shouting, yelling, shrilling – in up to 85% of people,
- Running away from the place of danger – in up to 70% of people,
- Calling for help – in up to 65% of people,
- Looking for a safe place – in up to 55% of people,

- Behaving calmly – in up to 25% of people.

In the majority of cases, the people's actions are manifested through a combination of several ways of emotional expression.

It is clear from the chart in Figure 1 that the most frequent way of manifesting emergencies by a human being is to make sounds that are accompanied by emotional phenomena.

This thesis proposes to use sounds/emotional words, that are uttered by human beings in emergencies, in order to control robotized, technological, or production processes [7]. A process shall be controlled by its stopping or placing it into the enhanced safety regime, in order to avoid damage to human beings' health [8].

3. The mathematical model for emotion identification in speech

The functioning of a safety system for such robotized processes that rely on voice emotions recognition is based on the mathematical model. The mathematical model will be implemented, based on a Neuronal Network that ensures the learning process and data processing for decision making.

There is defined the signal $u(t)$ that characterises the amplitude and form of a sound, which is perceived within the area of a robotized, technological, or production process. The emergency control system is made as based on a Neuronal Network, with the entry vector $X(t)=\left[x_i(t), i=\overline{1,N}\right]^T$ and the exit vector $Y(t)=\left[y_j(t), j=\overline{1,M}\right]^T$, or, to put it better, the decisional vector for multi-agent decision-making systems [9, 10]. The matrix $W=\left[w_{i,j}, i=\overline{1,N}, j=\overline{1,M}\right]$ has the multiplication factors, where: $Y(t)=WX(t)$.

The values of the entry vector $X(t)$ are calculated as based on the entry sound signal $u(t)$ and on the expressions:

$$x_1(t)=u(t); x_2(t)=\frac{du(t)}{dt}; x_3(t)=\frac{d^{(2)}u(t)}{dt^{(2)}}; ...; x_N(t)=\frac{d^{(N-1)}u(t)}{dt^{(N-1)}}.$$

Respectively, the value of the exit (decisional) vector $Y(t)$ is calculated based on the expressions:

$$\begin{cases} y_1 = w_{1,1}u(t) + w_{1,2}\dfrac{du(t)}{dt} + w_{1,3}\dfrac{d^{(2)}u(t)}{dt^{(2)}} + ... + w_{1,N}\dfrac{d^{(N-1)}u(t)}{dt^{(N-1)}}; \\ y_2 = w_{2,1}u(t) + w_{2,2}\dfrac{du(t)}{dt} + w_{2,3}\dfrac{d^{(2)}u(t)}{dt^{(2)}} + ... + w_{2,N}\dfrac{d^{(N-1)}u(t)}{dt^{(N-1)}}; \\ ... \\ y_M = w_{M,1}u(t) + w_{M,2}\dfrac{du(t)}{dt} + w_{M,3}\dfrac{d^{(2)}u(t)}{dt^{(2)}} + ... + w_{M,N}\dfrac{d^{(N-1)}u(t)}{dt^{(N-1)}}. \end{cases}$$

The Neuronal Network learning process is realized by using, at its entry, a set of sounds $U(t) = \{u_s(t), s = 1,2,3,...\}$, which determine the emergencies, and calculating the matrix $\left[w_{i,j}, i = \overline{1,N}, j = \overline{1,M} \right]$, in order to meet the condition: $WX(t) - Y(t) \approx 0$.

5. Conclusion

Scientific and technological progress needs engagement in the processes of robotized and mechatronic systems production. Although robotized and mechatronic systems have various methods and techniques for ensuring vital security, there may also occur emergencies when the environment has changed and needs special intervention in the process of robotized system functioning. Meanwhile, human beings still are present in the area of robotized systems' activity, and this is a factor of risk for health. A method to minimize the emergency consequences may be achieved by placing the robotized process into the enhanced safety regime or stopping it. It has been stated that the first reaction of a human being in an emergency is to make voice sounds that are emotionally affected, that are generated in a continuous and uncontrolled way, and that are used in order to influence the functioning of the robotized system.

This thesis proposes to use the emotions from voice sounds, which are made by human beings, in order to interfere into the process of functioning of the robotized and mechatronic systems. Aiming to do this, there have been classified emergencies, the way of manifesting such emergencies, and people's reactions to them; there has been also

developed the mathematical model that allows identification of voice emotions with the perspective of implementation thereof in Neuronal Networks.

The major contributions of this thesis lie in introducing the recognition of voice emotions in the context of robotized processes safety but this may significantly reduce the risks of unwanted accidents and incidents. This method has practical application in such fields as industry, medical aid, and others, where efficient robot-human cooperation is essential.

However, there still are limits in the accuracy of voice emotions recognition and in the adaptation to industrial robotized systems. Further research will be aimed at the improvement of such aspects due to the implementation of a safety system in the FPGA (field-programmable gate array) architectures and to standardization of safety systems of robots and mechatronic systems.

Acknowledgments. The research presented in the paper is part of the topic of doctoral theses from the Department of Computer Science and Systems Engineering, Technical University of Moldova.

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Revitalization of Scientific Publications by Hedy

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Abstract

The presented work refers to implementation of Digital Science concept. The essential component of digitizing scientific research is the revitalization of existing printed publications. This process aims not only to provide access to publications by making them suitable for digital archives but also to enable the reuse of their content in new works. We propose a technology implemented as an online platform, which facilitates the creation of fully digitized copies of scientific papers, including heterogeneous elements.

Keywords: Digital Science, online services, scientific publication digitization, document recognition.

1 Introduction

The concept of digital science involves the creation of digital institutes and laboratories. The digital transformation of their research activities primarily involves the digitization of such an important aspect as scientific publications. Currently, new publications are exclusively created in digital formats, with a wide range of software products available for this purpose. However, another essential component of digitizing scientific research is the revitalization of existing printed publications. The revitalization not just provides access to publications in digital archives but also enables the reuse of their content in new works.

Both activities of publication creation and revitalization are one-time, which makes them suitable for processing by online services. Today all popular online scientific archives and libraries offer diverse revitalization services.

Nevertheless, this is still a challenge to provide a compact, comprehensive, and free online service accessible to all researchers for their personal use.

We propose a revitalization service implemented as an element of our current development – the online platform Hedy [1]. The proposed service allows the creation of fully digitized copies of scientific papers, encompassing all their constituent elements.

2 Revitalization of Scientific Publications

The idea of proposed service arose in our research of heterogeneous documents digitization. We found out that full digital scientific documents are needed not only for providing free access but mostly for using elements of previous works in new ones. In our practice, digitization of images of mathematical formulae was used for book re-edition. Digitization of chemistry structures image is required to re-work images for stereo standard. Digitization of flowchart was needed for re-using of grammar schemes by our colleagues.

There is a need for the service of digitization of scientific publications that digitizes all heterogeneous elements. Besides comprehensiveness, this service should be suitable for the one-time work of scientific researchers: free, convenient, easy to use, with an intuitive interface.

Whereas for the representation of the text digitization results, it is enough to install the corresponding font, for heterogeneous content, the description by a script is required [2].

Based on the analysis of scientific researchers' requests, we selected for the first version of the proposed service the following heterogeneous content types: mathematical formulae, music scores, technical drawings, data charts, and chemical structures.

We chose the following scripts for selected heterogeneous document elements:

- *Latex* for mathematical formulae and technical drawings;
- *MusicXML* for music scores;
- *Combined CVS* for charts;
- *MOL* for chemical structures.

The proposed revitalization service produces as result full digital copy of the source scientific publication, where every specific feature of plain text is represented by the corresponding font, and every heterogeneous document element is mapped to due scripting description.

3 Proposed Service Implementation

HeDy web platform, developed using Python and Javascript, integrates the processing stages of heterogeneous documents into a digitization cycle, comprising the following main steps:

- uploading scientific publication source as images or PDF files;
- preprocessing of source (optional);
- identify the heterogeneous content;
- split it into fragments according to heterogeneous content types;
- analyze and recognize;
- preview, verification and editing (optional) of the results;
- saving the results.

The user interface is designed as a dialogue-based system, utilizing APIs on both the frontend and backend. The APIs set includes both server-based and online modules.

The stages are presented by the side menu that makes the digitization process returnable. Each step includes submenus where users can choose from various options or tools. For example, the image preprocessing tool can be selected from the radio-buttoned list: FineReader, OpenCV, ScanTailor, Gimp. Another example can be noticed at Fig.2, where the tool for OCR can be chosen from drop-down menu.

The most important stage is processing of heterogeneous content. The process can not be done intuitively, so each step is supplied by

help button. In Figure 1, the stage of classifying the heterogeneous content is presented. In case, when user's request is a homogeneous publication, the service allows quick processing without fragmentation step. This option can be activated by checking the corresponding radio button.

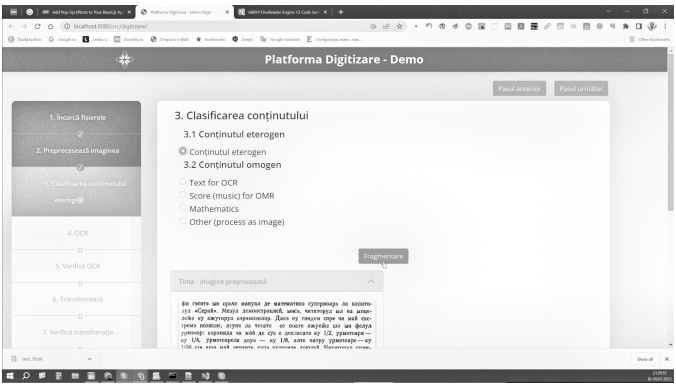

Figure 1. Classifying the heterogeneous content stage

In case of heterogeneous content, the button "Fragmentation" activates the corresponding stage (Fig. 2). The source image of document

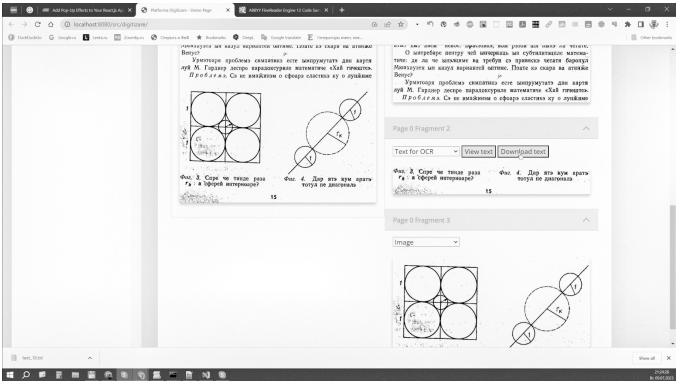

Figure 2. Fragmentation the heterogeneous content stage

is segmented into homogeneous components. Each type of the document contents is recognized by its specific engine (FineReader, Mathpix, etc.). The recognition works at backend showing "clock" on the screen.

The results of recognition are textual or script presentations of the content. These results appear on the screen together with toolbar for their processing.

There is an optional stage of verification and correction of the results, but this stage can be skipped and results can be saved immediately.

Verification of non-textual elements in the current version has to be done manually, but tools for correction are supplied by the proposed service. All these tools are also either the free server-based or online APIs.

4 Conclusion

This work considers the digitization of scientific publications that is the most noticeable scientific activity.

We propose a technology for the revitalization of scientific publications by the creation of fully digitized copies of scientific papers, encompassing all their constituent elements, including heterogeneous content. All heterogeneous content elements are presented in ready-to-use digital form by corresponding scripting.

The technology is implemented by the service of HeDy online platform with user friendly interface.

The revitalization service is compact, but comprehensive enough for daily use by scientific researchers. But the most important feature is that the service is free, since the backend consists of free or open source tools.

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Wizard Virtual Reality Game

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Abstract

The objective of this study is to merge the disciplines of Game Development and Virtual Reality (VR) in order to create an application that surpasses the immersive and complex nature of current Google Cardboard simulations. As a result, we introduce the Wizard VR Game, an engaging virtual reality experience that transports players into a mesmerizing realm, enabling them to assume the persona of a wizard and wield magical powers for their survival. Inspired by J.K. Rowling's renowned Harry Potter series, which features characters employing wooden wands to cast spells, our game integrates a similar mechanism to enhance user interaction and enjoyment. This approach not only enhances entertainment value but also serves as a means to enhance reflexes and promote hand-eye coordination. Furthermore, the game provides users with the option to navigate the virtual environment through joystick controls, enabling movement without physical space constraints.

Keywords: VR, Game, 3D Modelling, User Experience.

1 Introduction

Over the past decade, the advent of Augmented Reality/Virtual Reality (AR/VR) technologies has reshaped the video gaming industry, emphasizing immersive player experiences and direct feedback [1]. While Virtual Reality (VR) is often synonymous with leisure and entertainment, its profound implications span vital sectors such as Medicine [2], Education [3], Games [4], Culture [5], and Simulation and Training [6]. This widespread applicability accentuates VR's unique prowess:

the ability to provide users with unparalleled immersion in fantastical realms, granting experiences unattainable in our tangible reality. The emergence of devices like Oculus Quest and HTC Vive, complemented by Facebook's audacious unveiling of the Metaverse, echoes the surging enthusiasm and potential vested in this domain. Yet, as VR becomes more intertwined with our daily routines and professional pursuits, it's evident that challenges, like ensuring intuitive and realistic interactions in dynamic virtual environments, persist [7]. These nuances become especially significant in applications demanding utmost precision, such as medical training or flight simulations [8].

To address this overarching challenge, our research proposes a cutting-edge framework designed to amplify interaction fidelity within VR environments. We place a particular emphasis on applications that necessitate detailed accuracy and swift responsiveness, aiming to bridge the existing gap and push the boundaries of what VR can achieve.

2 Similar Applications

Blending diverse elements of the gaming world, "Wizard VR Game" integrates mechanics inspired by MOBA games such as World of Warcraft[1] and draws from the enchanting universe of Harry Potter [9]. What sets "Wizard VR Game" apart is its innovative spell-casting system using hand gestures recognized by the VR hardware and a dynamic dueling system where player choices directly influence the flow of the duel[2]. While it might echo certain mechanics from other games, its combination of real-time spell adaptation, player-driven narrative choices, and a strong emphasis on player feedback creates a game experience that is distinctly its own.

The Elder Scrolls V: Skyrim VR – Starting as a globally praised PC game, it ventured into VR to allow players to engage in its enthralling blend of exploration, combat, and character progression[3].

[1] https://worldofwarcraft.com/

[2] https://www.dualshockers.com/dnf-duel-combat-system-mechanics-guide/

[3] https://elderscrolls.bethesda.net/en/skyrim

Players face progressively challenging adversaries, earning greater rewards. However, where Skyrim VR focuses primarily on exploration and combat, "Wizard VR Game" introduces a comprehensive magic wand system where players need to fight specific creatures in order to advance into the game and acquire better resources. Additionally, our game offers a deeper integration of player decisions impacting the world's political and magical balance.

Beat Saber – A leading VR-exclusive title, Beat Saber provides an exercise-centric experience, where players slice cubes in rhythm[4]. Its focus on body movements and hand-eye coordination, backed by compelling VFX, has earned its massive popularity. In contrast, "Wizard VR Game" emphasizes strategy and precision through a rhythm-based wand dueling system, appealing to players who desire a blend of cerebral challenges and physical interactivity.

Other Major VR Titles – There's no denying the impressive lineup of VR games, from Fallout 4 VR[5] to Resident Evil 7 VR[6]. The burgeoning trend of Metaverse integration and cryptocurrency utilization in VR suggests a promising horizon for VR gaming. However, "Wizard VR Game" aims to pioneer in-game magical creature trading by achieving greater magical objects while you go further into the game and pass multiple creatures you encounter in the game. This innovative feature sets it apart from the existing VR titles.

Gaps in Current VR Gaming/Applications – While the VR gaming landscape has seen tremendous growth, there's a palpable absence of titles that truly integrate player actions and decisions into the fabric of the game world. Many offerings provide impressive visuals but lack depth in gameplay mechanics or fail to leverage the immersive potential of VR technology fully. Players often crave a more holistic experience, where their decisions resonate within the game's narrative and environment.

[4]https://beatsaber.com/

[5]https://store.steampowered.com/agecheck/app/611660/

[6]https://store.steampowered.com/app/418370/Resident_Evil_7_Biohazard/

3 Proposed Solution

Wizard VR Game is a Virtual Reality application meticulously crafted for the Oculus Quest 2 platform, including its headset and controllers developed by Facebook. This game is specifically designed to mitigate the occurrence of motion sickness commonly associated with VR headsets, making it accessible to both XR technology enthusiasts and avid video game players seeking novel and immersive experiences. Every aspect of Wizard VR Game, from the intricately designed 3D models to the captivating Virtual Effects (VFXs) and animations, has been personally developed by our team. In addition, we have utilized open-source libraries and APIs recommended by Unity, as well as sought valuable insights from dedicated forums on the Unity website throughout the development process. Wizard VR Game in Unity comprises four scenes that guide the user seamlessly through the application. Starting with the menu scene, players are directed to the immersive world in the second scene. The final two scenes represent the outcomes, with one for winning and the other for losing the game. These carefully crafted scenes ensure a smooth and engaging user experience.

3.1 Game Scene

The Game scene serves as the primary setting for the gameplay, employing multiple managers to maintain and track the current status of the game (refer to Figure 1).

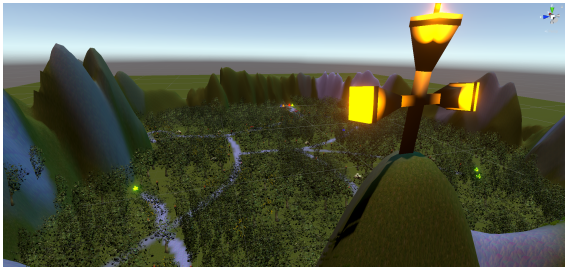

Figure 1. Game scene

- **The Player Manager** constantly monitors the player's health points at every frame. If the health points fall below zero, the player is redirected to the losing scene. The health points can only decrease when the player is struck by an enemy projectile.

- **The Game Manager** continuously monitors the number of active monsters and crystals in real time. To achieve victory, the player must eliminate all monsters and destroy the crystals scattered throughout the map. Each monster and crystal possess unique characteristics and are spawned at different locations. When the count of monsters and crystals reaches zero, the player is automatically directed to the winning scene. Notably, destroying a crystal or a barrel on the map rewards the main player with an additional 5 seconds, effectively extending the remaining time in the game.

- **The Enemy/Boss Manager** assumes responsibility for monitoring various parameters related to the boss, including the current health bar, speed, shooting range, and projectile accuracy. Enemies exhibit distinct behaviors, characterized by differences in projectile type, attack range, speed, damage output, and accuracy.

- **The Time Manager** keeps track of the remaining time in the game and calculates the player's score based on their remaining time and health points when they win. If the player successfully defeats all the creatures and destroys the crystals within the remaining time, they win the game and their score is calculated and saved. If the current score is higher than their previous best score, it replaces the old record, ensuring their achievements are recognized.

3.2 Unity Terrain API

Unity Terrain is a convenient API package that simplifies terrain and environment creation in Unity. Instead of manually shaping a basic

plane object, developers can use the Terrain object type and ”paint” new features onto it. An impressive feature is the ability to incorporate Blender models for trees, rocks, and grass, automatically adjusting their placement based on the terrain's height. This integration streamlines the workflow and enhances terrain creation in Unity.

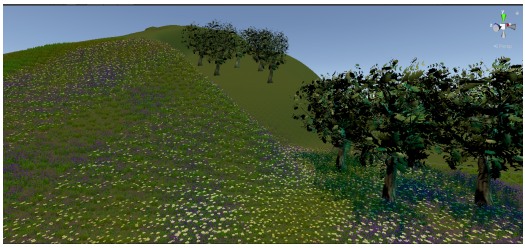

Figure 2. Unity Terrain Perfect alignment on Raised/Lower scenarios

3.3 Unity Artificial Intelligence - Navmesh Agent

In Unity, a NavMesh is a specific mesh within your scene that defines navigable regions in your environment. It identifies areas where characters can walk and identify obstacles that should be avoided. The NavMesh functionality proves valuable in scenarios that involve pathfinding and AI-controlled navigation. By utilizing the NavMesh Agent component, characters can intelligently avoid collisions with each other, move towards a shared objective, and navigate spatially complex environments. This capability extends to any scenario that requires spatial reasoning or pathfinding.

After baking a NavMesh for the level, the next step involves creating a character capable of navigating the scene. This is achieved by utilizing the NavMesh Agent component and implementing a corresponding script. NavMesh Agents offer flexibility in creating diverse pathfinding behaviors tailored to different character types within your projects. You can configure the NavMesh Agent to generate alternative behaviors by adjusting its settings and parameters. Experiment with different configurations to explore and implement unique pathfinding

behaviors for your characters. There are three different AI behaviors:

- **Normal AI Behavior**: For basic enemies, their behavior is stationary. When the player enters their range of vision, the enemies will begin to follow the player and launch projectiles to inflict damage. However, if the player manages to escape their line of sight in time, the enemies will cease pursuit and return to their initial positions.

- **Patrol AI Behavior**: In the case of basic enemies, they are assigned to patrol specific areas, following a predefined path that includes several checkpoints. Once the final checkpoint is reached, the AI will loop back to the first checkpoint and continue the patrol. If the player enters the enemy's field of vision during the patrol, the enemy will start pursuing the player and attack using projectiles. However, if the player manages to evade the enemy's line of sight in time, the enemy will return to the last checkpoint and resume patrolling the designated area.

- **Boss AI Behavior**: Higher-ranked enemies, such as bosses, exhibit stationary behavior. When the player enters their field of vision, they will not move but possess superior projectile movement, enhanced accuracy in determining the player's current position, and faster reload times for launching projectiles. This distinguishes them as formidable adversaries with increased capabilities compared to lower-ranked enemies.

3.4 XR Interactable Objects

In Unity, XR Grab Interactable objects are elements that can be seamlessly integrated into an XR interaction system using an XRInteractionManager. This integration enables the fundamental functionality of grabbing and manipulating objects within the XR environment. XR Grab Interactable objects can be easily attached to any desired object in Unity through the inspector tab, facilitating intuitive interaction within the XR space.

3.5 Character Creation Process

The characters in the application were created using Blender for modeling, rigging, and animation. However, during the project's transition to URP in Unity, the render and texture data needed to be reassigned to the objects due to compatibility issues. As a VR application, the characters were designed with a low-poly aesthetic to optimize graphics and enhance performance on VR headsets. This approach aimed to create an immersive user experience while minimizing the risk of VR motion sickness.

3.5.1 Modelling phase

As mentioned in the previous section on the creation process of 3D objects in the application, we also employ the widely used technique of subdivision to craft more intricate and complex 3D objects. To apply textures to our models, we employed UV mapping techniques to unwrap the models onto 2D surfaces.

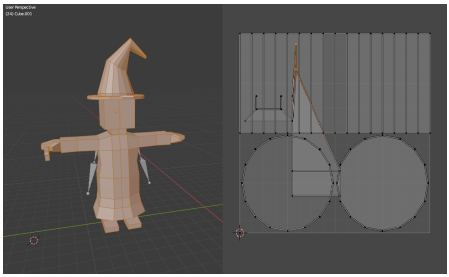

Figure 3. All the marked edges for the basic mage enemy with manual marking

3.5.2 Rigging phase

Rigging refers to the application of bones to create a skeletal framework for the character, utilizing small bone structures and joint connections.

This technique enables the animation of specific body parts without affecting the entire model, providing greater control and flexibility during the animation process.

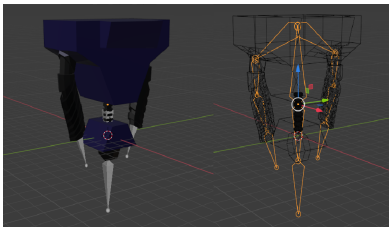

Figure 4. Enemy model in layout/wireframe mode with rig completed

3.5.3 Animation phase

The animations for the 3D models were crafted in Blender using keyframes to manipulate the armature. This allowed us to accurately control the position and rotation of each element throughout different frames, resulting in dynamic and seamless animations. Animation represents the process of posing the character in different positions using the skeleton build described above and inserting keyframes at every frame which basically are markers that store the position values of specific bones at a given frame.

3.6 Unity Particle System

During the development of Wizard VR Game, Unity's Particle System played a significant role in creating captivating visual effects throughout the game world. These effects included atmospheric elements like smoke, clouds, and rain, as well as dynamic elements such as flames, magic abilities/spells, and environmental movements. The flexibility of Unity's Particle System empowered us to enhance the immersive experience of Wizard VR Game with stunning visual effects. Integrating this API in Unity serves the primary objective of prioritizing user

feedback. An engaging game experience necessitates responsive feedback, such as visual and auditory cues when shooting projectiles at objects or enemies. Additionally, the inclusion of dynamic elements in the background enhances immersion, creating a captivating world for the player. By prioritizing user feedback, the main goal is to create an immersive and captivating experience that truly engages the end-user.

Figure 5. Falling leaves particle system

4 Usability Tests

Virtual Reality is an emerging field and testing applications can be challenging, especially when not everyone has access to a VR headset capable of running advanced applications. Without a headset, testing the Wizard VR Game became an almost impossible task. To overcome this obstacle, we devised a two-phase testing strategy for the game. This approach allowed us to tackle the testing process effectively and ensure comprehensive research findings. **First phase**: Before incorporating all the visual effects into the game, we initially showcased a specific video and offered support for VR headset usage. **Second phase**: Once all the visual effects were integrated into the application, we conducted another round of testing, including both video testing and live testing, to observe any changes in the feedback received.

4.1 Objective

Our primary goal was to comprehensively evaluate the Wizard VR Game's user-friendliness, interaction quality, visual appeal, and potential motion sickness effects. By conducting two strategic phases of testing, we aimed to not only improve game mechanics but also to understand how different user backgrounds influence their in-game experience.

4.2 First phase: Online Video

Participants: We selected a group of ten individuals comprised of eight boys and two girls. Their ages ranged from [e.g., 16-25], with diverse backgrounds in gaming, from novices to experienced gamers. Specifically, three had extensive experience with Unity development, providing a technical perspective.

Procedure: Every week, participants received videos highlighting various gameplay elements, from spell-casting to exploration. After viewing, they were provided with an online questionnaire, probing areas such as intuitive design, visual aesthetics, and perceived gameplay quality.

Results: The general consensus was a positive inclination towards the game's concept and interactive elements. However, a recurring suggestion was the enhancement of visual appeal, with four participants noting the potential for more immersive visual effects.

4.3 Second Phase – Live Demo Using VR Headset

Participants: A smaller, focused group of five individuals was chosen, ensuring a mix of genders and VR familiarity. These consisted of three boys and two girls, of which three had never before experienced a VR game.

Procedure: We provided our Oculus Quest 2 headsets, allowing participants to interact with the game directly. They were tasked with exploring the game environment, casting spells, and engaging with in-

game mechanics for a duration of 15-30 minutes. After their session, participants were requested to fill out a feedback form, which included questions about their experience, motion sickness levels, and any suggestions for improvement. Motion Sickness Assessment: A scale of 1-5 was used, with 1 indicating severe discomfort and 5 meaning no motion sickness.

Results: Three participants had past motion sickness experiences with VR. However, during our testing, these testers rated their discomfort at 3 and 4. Notably, a first-time VR user did not experience any discomfort.

4.4 Standardized Tools Used

During both phases, we also incorporated the System Usability Scale (SUS) to measure the game's perceived usability. The Wizard VR Game garnered an average SUS score of 82.5, indicating a high level of user satisfaction. Additionally, the NASA TLX was employed to assess the perceived workload, providing insights into the game's cognitive and physical demands on users. The feedback provided by testers during the usability testing phases played a crucial role in shaping the final version of the Wizard VR Game. Incorporating their suggestions, including the addition of more visual effects, projectiles, and adjustments to VR controller mechanics, greatly enhanced the overall quality and user experience of the application. Their valuable input proved invaluable in refining the Wizard VR Game.

5 Conclusion

Wizard VR Game, tailored for the Oculus Quest 2 headset, synthesizes intriguing game mechanics and a captivating wizardry theme to offer a unique virtual adventure. This project was not just about creating an immersive game but about delving deep into the research and understanding of user experience within virtual reality.

Our rigorous usability tests, two-phase testing strategy, and continuous iterations based on feedback set the foundation for its design. These research-driven methods were vital in ensuring the game's seamless and intuitive interface, catering to both VR novices and veterans.

Created entirely by our team, every asset in Wizard VR Game reflects our commitment to originality and quality. We view this application as more than just a game—it's a testament to the potential and the future of virtual reality. Through our research and development endeavors with Wizard VR Game, we hope to contribute valuable insights to the ever-evolving VR domain and inspire further explorations in this exciting field.

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Fake news detection on the internet: an overview

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Abstract

In recent years there has been a rise in fake news across the internet. This problem makes us ask ourselves how one can verify the veracity of claims inside a news article. Growth in social media platforms over the years has facilitated an enhancement in human communication. Platforms such as Facebook and Twitter are most ever-present in our lives and influence how we speak, think, act, and interact. The growth of fake news greatly impacts this phenomenon as it lowers one's trust in the content presented. Dangerous is also the fact that readers can be behaviorally and psychologically profiled to be served specially crafted content with the intention of changing one's opinion and action. One such example is related to the 2016 U.S. presidential election campaign where fake news was a deciding factor in tipping the balance of power and outcome. It is hence of critical importance to develop tools that detect and combat such destructive content. This work focuses on fake news detection and analysis.

Keywords: Fake news, Natural Language Processing, Natural Language Inference.

1. Introduction

Advances in computing, which heavily started at the beginning of the millennia, have drastically changed human interactions. No longer do we need to meet in person with other people to socially interact. It is very common nowadays to maintain close relationships with friends exclusively online. The COVID-19 pandemic has further progressed this movement, forcing us for months at a time to exclusively dialogue via digital means. Moreover, social platforms have steadily taken a more

universal role in our lives, providing most of the content consumed by a person in a day. We no longer buy newspapers, magazines, and books, nowadays we get this information online. The benefits are easily seen, it is more convenient, faster, and more environmentally friendly for us to read in a digital format.

The problem comes when news outlets also adopt this strategy of copy-pasting from social networks resulting in a snowball effect, where people take the information presented for granted, and other news outlets feel the need to relate the same information. The end result is obvious.

Another trend related to fake news is misinformation. It seems that with the rise of "Cambridge Analytica"[1] so did the misinformation campaigns that target people in order to influence certain beliefs so that certain entities can achieve their goals.

Considering the previous arguments, it is hence vital that the online environment must be a "clean place", ridden of fake news, propaganda, misinformation, and so on. Unfortunately, this is not the case; as [1] outlines, since 2016, the fake news phenomenon has been on the rise and it will only worsen.

This paper analyzes multiple techniques for detecting fake news.

2. Problem of fake news

We believe it is very important for us to define what is "fake news", as this can be interpreted very widely.

Oxford Dictionary defines the noun "fake news" as: "false reports of events, written and read on websites"[2] whilst Dictionary.com reports the term as: "false news stories, often of a sensational nature, created to be widely shared or distributed for the purpose of generating revenue, or promoting or discrediting a public Tableure, political movement, company, etc."[3].

We can thus see a pattern; fake news is regarded as inaccurate stories with the specific purpose of manipulating the general public to serve a

[1] https://www.theguardian.com/news/series/cambridge-analytica-files
[2] https://www.oxfordlearnersdictionaries.com/definition/english/fake-news
[3] https://www.dictionary.com/browse/fake-news?s=t

private agenda. Most often these stories are shared online through social media where regulation is scarce.

2.1 Origin

The origin of the term, in its current form, can be traced to the 2016 US elections, where a massive campaign of misinformation was led by Donald Trump with the help of Cambridge Analytica and the Russian Government.

Figure 1 highlights the use of the term "fake news" across the years; it can clearly be seen that starting with the 2016 elections, the term had a massive surge in popularity.

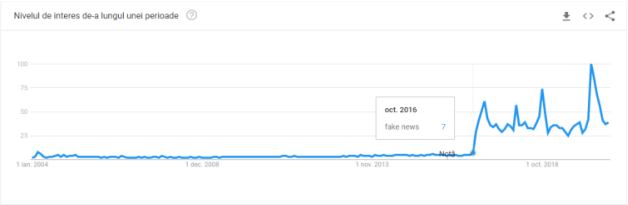

Figure 1. Google Trends regarding fake news searches

The Trump Campaign backed by Cambridge Analytica (which ran a "digital campaign") started building user profiles using Facebook data (which was officially taken through the public API) with the purpose of specifically targeting them with specially crafted news stories (fake news) so that they will be convinced to vote for Trump.[4] On the other hand, the Russian Government had the task to discredit its opponent, Ms. Clinton, through any means necessary; this meant an arsenal of tactics such as: creating thousands of fake social media accounts and supporting radical political groups, hacking the Democratic National Committee servers and exposing private documents, and the list goes on.[5]

3. State of the art

In this section, we will detail common solutions that others have implemented in the scientific community.

[4] https://www.theguardian.com/news/series/cambridge-analytica-files
[5] https://time.com/5565991/russia-influence-2016-election/

The two main approaches are linguistics with the AI approach and social networking approaches.

Linguistics with AI approaches

The first approach is related to natural language processing combined with machine learning, and has seen the following methods: apply n-grams and feed them to a classification algorithm in order to obtain a result [2] fast identify patterns of fake news using neural network (Sneha et al., 2018).

Hadeer [2] aims to "investigate and compare two different features extraction techniques and six different machine classification techniques". They compare n-grams with multiple machine learning algorithms; the tested models are SVM, LSVM, KNN, Decision Tree, SGD, and Logistic Regression. The n-grams tested range from unigram to four-gram. The best result yielded is "using Term Frequency-Inverted Document Frequency (TF-IDF) as feature extraction technique, and Linear Support Vector Machine (LSVM) as a classifier, with an accuracy of 92%". The dataset consists of 12,600 fake news articles from Kaggle.com and 12,600 truthful articles. Figure 2 highlights the classification process.

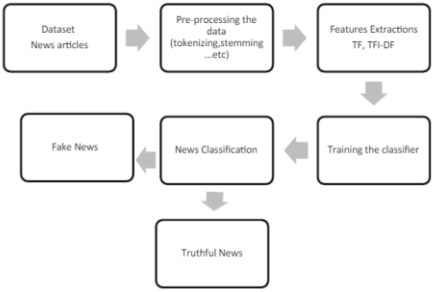

Figure 2. Hadeer classification process [2]

Sneha in [3] employs "a deep learning-based automated detector through a three-level hierarchical attention network (3HAN) for fast, accurate detection of fake news". This model analyzes each sentence and gives a score accordingly, being relevant for not having an opaque structure. They designed a three-layer attention mechanism in order to analyze the relationships between words, sentences, and headlines. "HAN is used to form a general document representation". The full architecture can be found in Figure 3. "Experiments on a large real-world news data

set demonstrate the superior performance of 3HAN over all baselines with 3HAN performing with an accuracy of 96.24%. Our pre-trained 3HAN model is our best-performing model with an accuracy of 96.77%".

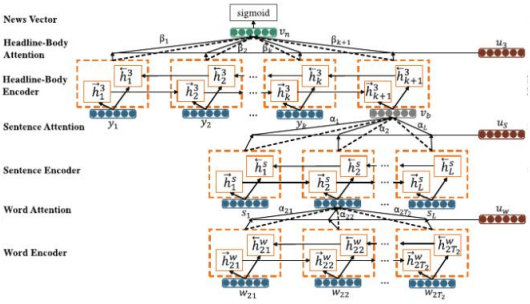

Figure 3. 3HAN architecture [3]

Social Networking approaches

The second approach sees the use of social networking in order to detect fake news. [4] states that fake news is such a prevalent problem as "social media for news consumption is a double-edged sword. On the one hand, its low cost, easy access, and rapid dissemination of information lead people to seek out and consume news from social media. On the other hand, it enables the wide spread of "fake news", i.e., low-quality news with intentionally false information". They continue to describe the fake news phenomenon and the diverse motives behind it (as already analyzed). They analyze different techniques and state that a combination of AI and social networking is best, "additional social context features can also be derived from the user-driven social engagements of news consumption on a social media platform. Social engagements represent the news proliferation process over time, which provides useful auxiliary information to infer the veracity of news articles". In order to test these feature extraction techniques they used an SVM model and five-fold cross-validation, with accuracy, precision, recall, and F1 measures averaged over the five iterations; they found that the best method is derived from "readability" followed by a combination of all the linguistic feature sets. Figure 4 illustrates one technique used, which is the transition from characterization to detection.

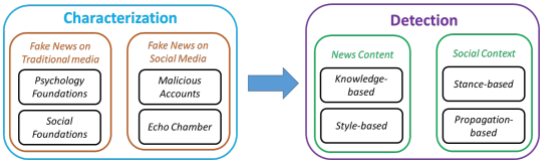

Figure 4. Fake news on social media detection [4]

4. Systems implemented so far

4.1 Bidirectional transformer for commonsense validation

A mechanism we considered useful in order to combat fake news was that of commonsense. With this idea in mind, we participated at "SemEval" 2020 with Task 4 – "Commonsense Validation and Explanation". The goal is pretty simple: machines can actually do a good job at complex knowledge tasks but lack the skill in commonsense reasoning.

In [5], they explain the reason for starting the SemEval Task 4. Their underlying motivation is that NLU (Natural Language Understanding) systems have become very powerful but have problems with commonsense reasoning. A fairly simple task that can be done by almost any human is very difficult for a computer.

The first model is state-of-the-art in commonsense reasoning with much better performances than any other available model, it's called BERT (Bidirectional Encoder Representations from Transformers) [6]. This language model is based on a unit of attention called a "Transformer" [7]. The idea is the following: the Transformer is an attention mechanism that uses an encoder and decoder in order to be very performant and obtain a very high BLEU [8] score. BERT uses this Transformer for developing a deep bidirectional representation of the unlabeled text. This language model after training can be used in a multitude of tasks: question answering, language inference, and machine translation.

Another model, but not as performant as BERT, is ELMo (Embeddings from Language Models) [9] which is also similar to an attention model but uses an LSTM for it. The architecture is comprised of 2 layers of LSTM and it is shallow bidirectional and extracts embeddings. The end scope is the same as BERT.

Table 1 presents the results of these two models in the SemEval evaluation methods.

Table 1. Performance of language models (Wang et al., 2019)

Model	Task 1 Choice	Task 2 Explanation
ELMo	69.4%	33.4%
BERT	70.1%	45.6%
Human	99.1%	97.8%

Our approach is described in [10]. The data set has been provided by the organizer [5] and contains the following: the training set containing 10,000 sentence pairs, the trial set with 2,021 pairs, the dev set with 997 pairs, and the test set with 1,001 pairs.

A training data example is the following: id: 3, Sentence 0: A mosquito stings me, Sentence 1: I sting a mosquito, answer 1.

As seen in previous BERT models, the data needs to be padded and tokenized; this is also the case with this model.

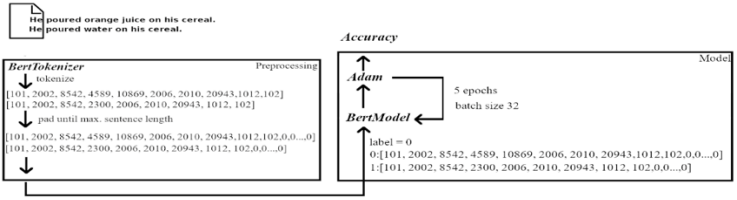

Figure 5. System architecture

It is based on a pre-trained model called “bert-large-uncased”; it is a bidirectional transformer that contains 24 layers, 1,024 hidden layers, 16 heads, and 340 million parameters. The language model chooses between 2 sentences so the output will be either 0 or 1 (first or second sentence). The system architecture can be seen in Figure 5.

The experimental setup is that the model was trained only with a 12-core CPU and 32 GB of RAM, a setting which proved to be very inefficient as training time was very lengthy, taking up to 24 hours with 5 epochs and 48 hours with 10 epochs. We tried running the model in Google Collaboratory 12 and managed to train on GPU; however, due to time constraints, we were not able to run as many experiments as we wanted or to fully optimize the model.

We got very good results: in the competition, the model ranked 17th out of 45 submissions with an accuracy of 89.1%. This result is in line with what we were able to predict from tests and what we expected to score (with a minor difference, of course). After a couple of parameter tunings, we managed to get a score of 92% in post-evaluation.

4.2 Commonsense explanation

Because our system in Section 4.1 had good results, we decided to implement a neural network that was capable of generating a response of why it chose a certain sentence.

This task is also based on SemEval 2020 however it is Task C. It requires a system to generate reasons why a given phrase is against common sense. An example is in the following box: *Statement: He put an elephant into the fridge., Explanations: 1. An elephant is much bigger than a fridge., 2. A fridge is much smaller than an elephant., 3. Most of the fridges aren't large enough to contain an elephant.*

The training dataset consists of 10,000 statements with explanations. Each system requires 3 explanations for why a phrase is against common sense. For example, *Id: 0 Statement: He poured orange juice on his cereal.*

The above statement has 3 explanations that a system can train on:

Id:0
Orange juice doesn't taste good on cereal.
Orange juice is poured into a glass.
Orange juice does not taste good on cereal.

The model initially sought after was GPT-3 [11]; however, since it is not public, we had to resort to GPT-2 [12]. We used the 345 million parameters model but also experimented with the 117 million one. The capability of GPT-2 we are interested in is called "interactive generation" and, based on an input sample, it generates the continuation of the sample until it reaches the "End Of Sequence" token.

To adapt our problem to the capability of GPT-2, we have arranged the training set in pairs of proposition-answer samples followed by a new token, "<|endoftext|>" and a newline (e.g., "Elephants eat helicopters. Helicopters are not food. <|endoftext|>"). GPT-2's "End Of Sequence" token is not necessarily at the end of a sentence, it can appear in the middle of a sentence, so we need a way to separate samples. Our novel

token is added in the byte-pair encoding of the model, and then learned by it, so when it generates new samples, it will delimit them by that token.

We needed about 5000 iterations of fine-tuning until the loss function was not decreasing anymore and we could conclude that the model was well enough tuned for our problem. The interesting part about GPT-2 in this case is that it has also learned to generate illogical sentences since it has encountered plenty in the fine-tuning process. To get an explanation for our input illogical sentence, we just need to feed the illogical sentence to the GPT-2 model, followed by a full stop to mark the end of a sentence. Since it was fine-tuned on pairs looking like "<Illogical sentence. Logical explanation>", it has learned that after the illogical sentence and a full stop, the logical explanation is followed, so it will generate it.

The metric for testing is BLEU [8] and it outputs a continuous value between 0 and 1. This value indicates how similar the candidate text is to the reference texts, with values closer to 1 representing more similar texts. We ran tests on 1000 sentences in the training dataset (10% of data) and arrived at an accuracy of 75%.

While testing manually, we selected 100 samples to analyze by hand and observed that the model has good explanations, for example, "Birds like to stay in the same location all year long.", the model returned: "Birds go extinct when they only joined a location once in a lifetime." However, there are some cases where the explanation is completely irrelevant, for example: "I got ready for bed so I drank a cup of coffee.", the model returned: "coffee = liquid not solid."

4.3 Fake news detection algorithms experiments

In order to experiment with multiple algorithms, we used the CLEF CheckThat! 2021 Task 3a [14] [15]. They have the goal of identifying fake news with the task definition being: "given the text of a news article, determine whether the main claim made in the article is true, partially true, false, or other (e.g., claims in dispute) and also detect the topical domain of the article". In the competition, we submitted 5 different models and overall ranked 6th. The training dataset consisted of 945 labeled articles, and the test dataset had 365 unlabeled articles. An example of the dataset entry is: public_id: c7ea6a6e, text: New evidence ties COVID-19 creation to research funded by Fauci?, title: Flooding of

Coast, Caused by Global Warming, Has Already Begun., our_rating: false.

3Layer Model

The first model, and the one which has proven to be the most performant, has been named the "*3Layer Model*" because of its use of 3 different preprocessing methods and 3 different Machine Learning algorithms.

In the data preparation phase, there have been a series of alterations to the dataset. The *public_id* field has been removed, the two training batches have been combined as well as the *title* field and *text*, punctuation signs have been removed as well as stop-words, dashed and underscores, and lastly, the text has been lowercased and lemmatized.

The feature extraction phase consisted of three approaches:

- ***Clean text*** is a bigram (a contiguous sequence of n items, where n is 2), the training column will be called ***clean_text***;
- ***POS Tagging*** on *text* column using spaCY to obtain the POS form), the training column will be called ***POS_text***;
- ***Semantic Analysis*** is done using Stanford's Empath Tool [16] to categorize the words in the articles by their lexicon and approximate which articles that are fake predominantly use a certain lexicon (this column was named ***semantics_text***).

Besides the three aforementioned techniques, we created a fourth one by weighting them as follows: clean_text: 0.5, POST_tagging: 0.15, and semantic_text: 0.35 (these values have been determined experimentally). On the columns mentioned earlier, clean_text, POS_text, and semantics_text, in order to feed the data to the M.L. algorithms, we applied TF-IDF.

As for the models used, they consisted of Naïve Bayes, KNN, Random Forest, and Gradient Boosting. The most performant variant consisted of Gradient Boosting combined with the weighted representation of clean text, POS tagging, and semantic analysis.

BERT

Another model developed is based on BERT which yielded great results in many state-of-the-art systems [6].

Data preparations for this method consisted of shuffling the training articles, concatenation the batches, merging the title and text columns, and eliminating *public_id* (it was redundant to training). Other operations have

consisted of punctuation signs removal, lemmatization, mandatory text padding, and a special BERT tokenizing process.

As for the model, we used *bert-large-uncased* (24-layer, 1024 hidden dimensions, 16 attention heads, 336M parameters) from HuggingFace and began the fine-tuning process. A problem immediately apparent was the size of the dataset, as BERT requires many training entities. We used AdamW Optimizer (fine-tuned the learning rate as well as possible, 6e-6 yielding the best results), 3 epochs, and a batch size of 3.

RoBERTa

RoBERTa [16] is a more powerful version of BERT, hence we were eager to use it and compare the results since it is similarly used in many novel systems. The pre-trained RoBERTa has been taken from HuggingFace as well, we used the model *'roberta-base'*.

The data processing is similar to BERT. The dataset has been split as follows: 70% of the data is for training, 20% - for testing, and 10% - for validation. Hyperparameters used are: text sequence is 256, batches are of 32 elements.

LSTM

The fourth implemented model is LSTM. Training and testing have been done on an 80-20% split. The data processing involves combining the title and text columns and then applying SnowballStemmer from NTLK to stem the text. The text has also been tokenized using Keras's Tokenizer.

Feature extraction uses Word2Vec as it preserves the semantic meaning of words in documents; using the resulting embedding matrix, we fed it to the model.

The model is built with Tensorflow and it's a combination of the following layers: embedding layer, dropout layer with a dropout rate of 0.3, LSTM layer with 100 units with a recurrent dropout (fraction of the units to drop for the linear transformation of the recurrent state) of 0.2 and a dropout of 0.2 (fraction of the units to drop for the linear transformation of the inputs), dense layer with 4 units (because we predict 4 labels), and using SoftMax activation function.

The loss function used was sparse categorical cross entropy with Adam optimizer. The total params of the model were 2,648,304. The optimum number of epochs found was 8 and the batch size was 16. We used callback functions such as ReduceLROnPlateau to reduce the

learning rate if the accuracy does not improve and early stopping to halt training if the model does not improve.

Bi-*LSTM*

The fifth and final implemented model is an improvement effort on the previous LSTM network. The dataset split was: 90% training and 10% validation.

The *title* and *text* columns were merged into a single column, much like all the models. The newly formed *total* column was then processed by removing every stop word and lemmatizing it using NLTK. Finally, the sentences were converted to lowercase and had their whitespaces removed.

The text was tokenized using the Keras Tokenizer. The word index generated length was 27401. For extracting the features, we used GloVe embedding (Global Vectors for Word Representation) with 100 dimensions. Training is performed on aggregated global word-word co-occurrence statistics from a corpus, and the resulting representations showcase interesting linear substructures of the word vector space.

For building the model, we used Tensorflow. The model was built using the Bidirectional LSTM architecture. We experimented with a lot of combinations of layers but the one that gave the best results during the validation stage was the following (in order):

- The embedding layer with the input dimension equaling the word index length (27401), the output dimension equaling the number of embedding dimensions (100), and the input length equaling the maximum sentence length from the training test.
- Bidirectional LSTM layer with 64 units and return sequences set to true.
- Bidirectional LSTM layer with 32 units.
- Dropout layer with dropout rate equaling 0.25 to better handle the overfitting due to the small dataset.
- Dense layer with 4 units (because it predicts 4 labels) and softmax.

The loss function we used was sparse categorical cross entropy with Adam optimizer. The total params of the model were 2,866,156.

As a result, we had 5 models, the best approach seems to be the **3Layer weighted method that officially has an F1-macro of**

0.4463072939. We were unable to calculate the other scores with the gold label and the organizers did not provide a ranking.

5. Conclusion

To conclude, in this paper, we outlined the main research directions of Fake news detection. It seems that the future is a combination of artificial intelligence and NLP, NLU, the most recent example being ChatGPT. For the future, we plan on building an integrated solution where we use a commonsense classifier as well as a commonsense reason generator in order to inform the user of our decision.

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Detect anomalies in images: an overview

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Abstract

Temperature variations, climatic changes, or human interventions are the main causes of buildings and streets deteriorate over time. Since manual verification of such structures completely depends on a specialist's knowledge and experience, it is often time-consuming, costly, and dangerous; therefore, an automated approach would be very beneficial. Automated devices using computer vision that detect anomalies in targeted structures have the potential of creating a better and safer environment, periodically checking for possible faults and improving worker safety. By automating computer systems, we can improve and monitor the process of identifying these cracks through applications that manage to detect such features. The article presents developed experiments for the detection of cracks and other particularities in images.

Keywords: Cracks, CNN, Asphalt, Android.

1. Introduction

Expensive investments are made annually to consolidate streets and bridges, however, for areas that are difficult to access and where human intervention is required, these operations are usually postponed. Consequently, the use of devices to recognize cracks using artificial intelligence techniques could be useful and efficient and provide better safety for workers. Time passage and the formation of cracks seems to be the main culprit for road degradation [1]. Road crack detection via manual on-site detection proves to be costly, time time-consuming and ultimately leads to postponed maintenance which in turn hinders traffic, raises maintenance cost for drivers and puts lives at risk [2]. A good example is

the Ponte Morandi bridge in Italy that in 2018 collapsed due to years of postponed work.

On the road, surface cracks, breaks, or landslides cause thousands of injuries and accidents every day, all over the world. Within the European Union, according to the official publications concerning the period 2003-2018[1], the number of fatal accidents has dropped sharply, registering 25100 deaths compared to 2003 when the number of deaths was twice as much. These improvements are due to the fact that over time, the maintenance of asphalt has been a priority. Resources have been invested both in environment engineering but also in computer research to obtain automated applications that identify as quickly as possible the anomalies that exist on the asphalt surface. It can clearly be seen how important this prevention is.

This paper presents techniques for detecting anomalies in images from engineering, biological, and medical fields.

2. State of the art

As previously said, this task is in great need of automation; however, nowadays, automation in the identification of cracks is not a common practice, and this field would greatly benefit from a computer vision model.

Modern structure monitoring solutions are used in some cases, which use image collection devices to identify cracks. Such monitoring can be done through drones that record the state of the roads and are assisted by humans. Another approach could be the installation of crack detection devices on electricity poles so that they will send constant data, and specialized crews can come and check a possible problem.

Crack detection is also done through automatic inspection where image processing technology is used. So far image processing techniques have been introduced as: neural network approaches, statistical approaches, and segmentation. OpenCV[2] and MATLAB[3] can also be used for easy monitoring of crack images [11].

[1] https://ec.europa.eu/commission/news/road-safety-2019-apr-04_en

[2] https://opencv.org/

Studies show a strong interest in identifying cracks and the methods constantly improve providing good results even when the images are blurred or in the wrong light [3]. In [4] and [5], the authors propose a new method and an application that can be considered an alternative building management agency in the task of building a condition survey.

Also, in recent years, many mobile applications for image processing have been developed. In [6], the authors present challenging tasks related to mobile image processing using both serial and parallel computing approaches in several emerging application contexts. In [7], authors take into account the quality of the images taken with the smartphone. For that, they present an approach to overcome the obstacles and stabilize the image-capturing process such that image analysis becomes significantly improved on mobile devices. In [8], the authors investigate the measurement and analysis of concrete crack features based on the Smartphone Application of Digital Image Processing Techniques (SADIPT) in the Android system. In [9], the authors present a nondestructive detection method for the concrete surface crack based on Android. After collecting the crack image area with the smartphone camera, they use more image processing algorithms in order to identify crack length, width, and area characteristics.

Deep Learning algorithms

Deep Learning algorithms, such as the Convolutional Neural Network, are often used to: detect certain patterns, recognize objects, or classify. Good performance is achieved through large data sets such as ImageNet[4], CIFAR 10 and 100[5], and MNIST[6] that contain millions of images and help the network achieve the right accuracy.

With the passage of time, each building begins to deteriorate. These adverse effects can be due to climate change (excessive heat or cold, in combination with rain, snow, and wind), earthquakes, or lack of interest in maintaining the strength of buildings. Specialized people who go to the

[3] https://www.mathworks.com/products/matlab.html
[4] http://www.image-net.org/
[5] https://www.cs.toronto.edu/~kriz/cifar.html
[6] http://yann.lecun.com/exdb/mnist/

site to inspect them visually usually perform the maintenance activities of a building. These experiences are often risky, difficult, and time-consuming. Crack detection done through an automatic inspection where image processing technology is used can increase worker safety and prevent further degradation of a building. So far crack identification with image processing has seen the use of the following approaches: neural network approach, statistical approach, segmentation [10].

Studies show a strong interest in identifying these anomalies and the methods constantly improve providing good results even when the images are blurred or in the wrong light [12]. In [13] and [14], the author proposes a new method and an application that can be considered an alternative for building management agencies in the task of building a condition survey.

In **Concrete Cracks Detection Based on Deep Learning Image Classification** [15], the article presents a developed mechanism that detects cracks. Researchers applied a deep learning convolutional neural network (CNN) image classification algorithm. They took into consideration several conditions, e.g., different light, surface finish, and humidity that a concrete surface might exhibit.

Another approach is **Deep Learning-Based Crack Damage Detection Using Convolutional Neural Networks** [12]. It used a CNN trained on 40k images of 256 × 256 pixels and has 98% accuracy. This mechanism was implemented for detecting civil infrastructure defects to partially replace human-conducted on-site inspections.

3. Work and experiments

3.1. Asphalt crack identification application

SYSTEM DESCRIPTION

This experiment aims to create a portable model for an Android application that can identify cracks. A public dataset provided by Kaggle [16] has been used for the model. This dataset contains around 11.200 images that are merged from 12 available crack segmentation datasets, but only 11.700 images were used. The dataset is comprised of images that depict asphalt with cracks or no cracks. Training is done on a dataset of approximately 10.000 files, pictures of cracks from streets with their respective labels which represent what the model should return. The

model is tested on a dataset of 1.700 images, examples can be seen in Figure 1. The labels are standard with a pixel format of 256 × 256.

An image generator was developed, in case not enough resources are available, essentially, it applies a combination of operations over the image such as flips, rotations, skewing, and corresponding mask creation.

Figure 1. Images example from the dataset

ARCHITECTURE DESIGN

The work presents an Android application capable of detecting cracks in a video input using real-time inference. First, a neural network model is trained, the model that was designed for the problem at hand using a dataset described in a previous section. The neural network based on U-NET was priorly trained and evaluated in order to reach a good accuracy, after which the optimization process began. The optimization is done with the purpose of reducing the computing effort on the phone's side whilst maintaining accuracy. Figure 2 shows the system overview; the idea is simple, the user (either a worker or autonomous machine) has the application installed on an Android device, and the application shows a camera interface that is able to automatically apply a label over the feed.

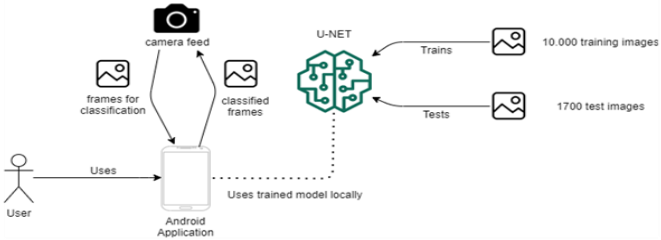

Figure 2. System overview

The workflow is that the camera sends frames to the TensorFlow model which in exchange produces a filter that is overlayed on the

original image. The model is exactly the one optimized on a local computer and loaded on an application with every deployment.

U-Net algorithm

As previously mentioned, the U-Net algorithm work started with what was originally done in [17] and [18]; however, it needed improvement so it could be used in our use case. The main problem was the fact that it was not developed to be lightweight since the model size and latency were large on the phone.

The model was trained with 10.000 images and tested with 1.700 images, labels had a 256 × 256 pixels float format that was converted to black and white. Tests conducted on how the algorithm handled images with or without color showed that there is no difference between the two (regarding accuracy and speed), hence a decision was made to convert all of them to grayscale prior to sending them to the system. This will also reduce image sizes and make the model faster on the phone.

To save the model in a reduced dimension, TensorFlow Lite was used; this mechanism allowed the serialized model to be compressed from an initial 350 MB to 100 MB which is a more reasonable size for any Android smartphone. Tackling the first problem, related to size, proved to be easy, as the model's high latency posed a challenge at that time. Unsure of what the problem was, the model started to undergo a thorough analysis, starting from the input data to how the model was structured. What proved to be best was removing layers in order to reduce computing time. The optimization process started with removing some of the upsampling and downsampling layers to obtain a smaller latency but kept the dropout to avoid overfitting. The upsampling and downsampling were used with 64, 128, 256, 512, and 1024 filters at first and the inference time was about 10s without the preparation of the input/output overhead. This is a very high result, so further refinement had to be made.

The actual model used in the Android application uses upsampling and downsampling with 32, 48, 64, and 96 filters. With these modifications, the inference time dropped from 10 seconds to 600-800 ms; this also included the overhead of the application that must also process the camera frames and convert the frames to a suitable format for the model. This removal of layer had another unexpected benefit, the size of the uncompressed saved model went down to ~ 6 MB (hdf5 format)

and further to ~ 1.7 MB compressed (float32 to float16 optimization and tflite format).

All these optimizations made the model lightweight and fit to be used in low-power phones, lowering costs for the detection process.

Android

In order to test the model and realistically aid the work of some people, an Android application was implemented with the ability to almost instantly classify road cracks. For the scenario to be realistic, it was decided that the software was not allowed to connect via the internet to some server, the reason being that in remote and dangerous areas (where, for example, a drone can be sent), internet speed would be a commodity hence the application only relies on the phone.

The Android application takes the frames from the phone's camera feed and identifies the cracks using the model described in the latter chapters. The model is trained as previously described and loaded on the application.

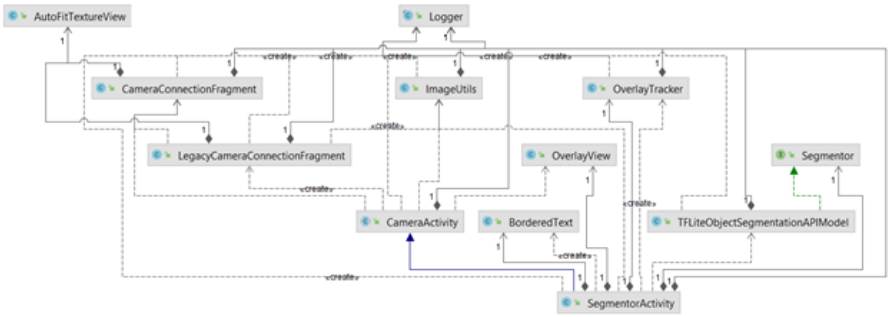

Figure 3. Application class diagram

The application has a simple but well-constructed architecture; in Figure 3 a minimalist UML class diagram can be seen, showing the interaction between components. The main class is the "SegmentorActivity" which basically assembles all the information in the application; it takes the camera feed and basically "blocks" the system until "TFLiteObjectSegmentationAPIModel" finishes the process of image analysis; the SegmentorActivity is also the one that can calculate the latency of the model.

TFLiteObjectSegmentationAPIModel initializes the TensorFlow session for classifying images. The model that is pre-trained has been detailed in the previous section; a new one can be included by deploying a new application or by creating a download mechanism. The class gets the frame as a buffer and it will transform it into a Bitmap image and preprocess it before sending it to the model; since the model expects the image to be black and white, a mask must be applied to be of proper format. The operations are the following and are standard:

- int red = (rgb >> 16) & 0xFF;
- int green = (rgb >> 8) & 0xFF;
- int blue = (rgb >> 0) & 0xFF.

After the preprocessing is complete, the loaded model is ready to receive inputs and Tensorflow Lite will output a bitmap image representing a mask with the areas that contain cracks.

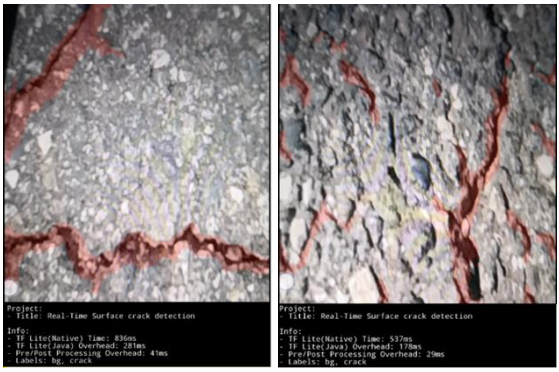

Figure 4. Left: Application output example before optimizations; Right: Application output example after optimizations

As seen in Figure 4 (left), the total time for segmentation and overlaying is about 1.2 s (836 + 281 + 41 = 1158 ms). Those images were taken from a demo in the first steps of developing the model, before optimizing the model. The inference time is about 70% of the total time. The overhead from the preprocessing and postprocessing of the data is relatively small, the focus being on optimizing the inference time for the model. This was also the main problem: because the resources on a mobile device cannot compare to a desktop, the testing on each of the models was done by installing the application and doing live tests on

several pictures with surface cracks to see if the inference time was improved. Models with a high range of filters for upsampling and downsampling (from 16 to 192) were used.

For example, one of the models used this configuration as several filters: "[24, 36, 48, 64]", others used "[32, 64, 128]". For each model, testing was done by putting the application in a real-life situation. The conclusion was that a small number of parameters in the neural network means a faster but less accurate segmentation. With this model, a balance between speed and accuracy was sought.

Figure 4 (right) presents the current implementation of the algorithm which can output in half the time of the experiment in Figure 4 (left). The photos and experiments have been done with a Google Pixel 4.

Evaluation results

In evaluating the model, 2 approaches have been taken: one is to load the model in the application and test it on a device, and the second approach was to see the training and loss accuracy. What we did is we would change the parameters of the network, and if the results were better than before, we would test with the phone on the same set of cracks to see if the training time went down. The first approach results can be seen in Figure 4, where we attached some sample runs of the application on different images. Concerning the second method, Figure 5 provides a visual representation of how accuracy fluctuates with different training durations. Additionally, the findings presented in Figure 5 demonstrate the following:

- The epoch accuracy at the end of the training varies between 94.3% and 97% (smoothed) for the validation data, and the epoch loss in time at the end of the training varies between ~ 0.05 and ~ 0.15 (smoothed) for the validation data.
- These results for the most relevant training sessions mean that the model is still in development, and optimizations for the number of epochs and steps for epochs can still be made.
- The usage of different numbers of filters for the sampling of the images has little to no effect in terms of altering the accuracy of the model.

Figure 5. Accuracy increases over time at training

Comparing the models with [19], it is easily seen that there is a difference between the author's maximum accuracy of 99.71% and this model's maximum result of 97%; however, the loss is also related to our optimizations; we especially lowered the accuracy in order to gain more speed and considering the precision is over 90% the result comparable. The same scenario can be seen in [20], where they have a similar result with [19], the maximum accuracy is 99.06%, a notable difference being that they trained using 60.000 images (almost 3 times our dataset) but tested on only 205 images.

Comparing the Android application, [20] also developed a smartphone application, on iOS in this case, that seems to have the same goals as the application presented in this paper; however, they do not share speed or how it is built, it is not clear either if the model runs locally or in a server. Work done in [21] seems to have the same goal as this work; they use a technique based on matrices to approximate the crack rather than AI and can run the calculations locally on a Huawei P20 Pro, and the accuracy "with error within ± 10% can reach 97. 5%", which is a similar result though time is not a dimension they take into account which is exactly the purpose of this application.

3.2 Crack detection system using CNN

In this work, we wanted to create a scalable model for crack detection and test it on a cloud. The first experiment started with a classical approach based on Convolutional neural networks and was inspired by the article "Performance Comparison of Pretrained Convolutional Neural Networks on Crack Detection in Buildings" [22].

In order to train, validate, and test our implementation, we used a public collection of images provided by [22]. This set consists of 40.000 images, each with a resolution of 227x227 pixels. Out of those images, 20.000 are positive, containing cracks, and 20.000 are negative, showing parts of buildings or roads that are intact. Some photo examples are in Figure 6.

Figure 6. Examples of crack images and one without crack

The architecture created by us is a web-based application, which detects cracks. The user uploads a photo via a web interface, and the application will return an image where the found anomalies are highlighted. In order to identify anomalies, we implemented two algorithms, both based on CNN networks. The approach proposed by us aims at building a distributed system. The results obtained by the experiments made on the running in AWS show that the application is scalable, it can support more users, such as engineers who want to observe the anomalies in the constructions. Specifically, users in parallel can use the application by entering images that they want to know in which area the cracks or fissures in the content are. The results are quite encouraging; the algorithm is able to classify correctly some cracks. The second CNN algorithm manages to separate the cracks in the picture (both the small, almost unnoticeable ones and the large crack) but has many false-positive findings, especially where the surface contains black points. No matter how many times this image is run, this algorithm will always find the same zones as positive cracks. The first CNN algorithm has a lower false-positive rate but cannot find all the small cracks in the image and even some portions of the bigger crack. Its behavior is non-deterministic, the results changing with each new detection on the same image. On our third CNN solution, we take 16 different iterations of the first algorithm and keep the zones found by most iterations, thus reducing the false-positive rate to at most two zones on the image.

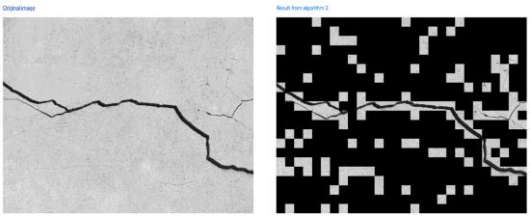

Figure 7. (a) Original image (b) Output result

The problem stems from the algorithm's incapacity to identify all minor cracks, which is apparent from Figure 7, where specific small cracks go unnoticed and unclassified. The next phase involves extending the training duration, fine-tuning the parameters, and establishing a reliable metric to assess its performance.

In order to offer scalability and fault tolerance, we decided to benchmark each solution in the cloud. We chose to use AWS EC2 instances having a 1.6GHz CPU with one vCore and 1GB RAM. We ran each test for about 10 minutes with 20 simultaneous requests. To show the scaling advantage of the cloud, we benchmarked the solutions running on a single EC2 instance versus running each one on a different EC2 instance.

We can observe that by running them on different machines, we can serve about 19.05% more requests (from 1,538 to 1,900). The number of errors decreased overall but slightly increased for Solution 2; this is in part due to the increased number of requests that it could handle. Median and average response time saw great improvements between 32-51%. Minimum response times were reduced by 50 times in the best-case scenario, and maximum response times were overall lower by 19%. Requests handled per second also improved by about 40%.

We can conclude, that the system created has a good performance using the third CNN algorithm with sixteen iterations. The main advantage of the third approach is having a higher crack detection rate thanks to the sixteen additional iterations. More so we gained good performance and scalability by doing experiments on the AWS cloud.

5. Conclusion

In this work, we defined the state of the art in crack detection, presented multiple models and experiments developed, from crack-detecting software to tuberculosis identification, and concluded with the idea of developing an Android framework for local classification.

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Bol-Moufang groupoids of order three up to isomorphisms

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Abstract

We list classical Bol-Moufang identities on groupoids of order 3 up to isomrphism that are given in [1].

Key words: groupoid, quasigroup, Bol-Moufang type identity.

We continue to count the number of non-isomorphic groupoids of order three with Bol-Moufang identities [2, 3, 4, 5]. We have the following final table.

Table 1. Number of groupoids of order 3 with classical Bol-Moufang identities: all and non-isomorphic.

Name	**Abb. Ident.**	**3**	**n.-is.**
F_1	$xy \cdot zx = (xy \cdot z)x$	314	61
F_2	$xy \cdot zx = (x \cdot yz)x$	196	40
F_3	$xy \cdot zx = x(y \cdot zx)$	314	61
F_4 middle Mouf.	$xy \cdot zx = x(yz \cdot x)$	196	40
F_5	$(xy \cdot z)x = (x \cdot yz)x$	874	158
F_6 extra id.	$(xy \cdot z)x = x(y \cdot zx)$	239	49
F_7	$(xy \cdot z)x = x(yz \cdot x)$	305	61
		Continued on next page	

F_8	$(x \cdot yz)x = x(y \cdot zx)$	305	61
F_9	$(x \cdot yz)x = x(yz \cdot x)$	221	26
F_{10}	$x(y \cdot zx) = x(yz \cdot x)$	874	159
F_{11}	$xy \cdot xz = (xy \cdot x)z$	260	49
F_{12}	$xy \cdot xz = (x \cdot yx)z$	223	45
F_{13} extra ident.	$xy \cdot xz = x(yx \cdot z)$	271	53
F_{14}	$xy \cdot xz = x(y \cdot xz)$	314	61
F_{15}	$(xy \cdot x)z = (x \cdot yx)z$	1456	253
F_{16}	$(xy \cdot x)z = x(yx \cdot z)$	404	73
F_{17} left Mouf.	$(xy \cdot x)z = x(y \cdot xz)$	164	35
F_{18}	$(x \cdot yx)z = x(yx \cdot z)$	344	61
F_{19} left Bol	$(x \cdot yx)z = x(y \cdot xz)$	215	40
F_{20}	$x(yx \cdot z) = x(y \cdot xz)$	601	110
F_{21}	$yx \cdot zx = (yx \cdot z)x$	314	45
F_{22} extra ident.	$yx \cdot zx = (y \cdot xz)x$	271	53
F_{23}	$yx \cdot zx = y(xz \cdot x)$	223	45
F_{24}	$yx \cdot zx = y(x \cdot zx)$	260	46
F_{25}	$(yx \cdot z)x = (y \cdot xz)x$	601	110
F_{26} right Bol	$(yx \cdot z)x = y(xz \cdot x)$	215	44
F_{27} right Mouf.	$(yx \cdot z)x = y(x \cdot zx)$	164	34
F_{28}	$(y \cdot xz)x = y(xz \cdot x)$	344	43
F_{29}	$(y \cdot xz)x = y(x \cdot zx)$	404	76
F_{30}	$y(xz \cdot x) = y(x \cdot zx)$	1456	252
F_{31}	$yx \cdot xz = (yx \cdot x)z$	296	54
F_{32}	$yx \cdot xz = (y \cdot xx)z$	295	53
F_{33}	$yx \cdot xz = y(xx \cdot z)$	295	54
F_{34}	$yx \cdot xz = y(x \cdot xz)$	296	56
F_{35}	$(yx \cdot x)z = (y \cdot xx)z$	923	164
F_{36} RC ident.	$(yx \cdot x)z = y(xx \cdot z)$	218	43
F_{37} C ident.	$(yx \cdot x)z = y(x \cdot xz)$	209	44
F_{38}	$(y \cdot xx)z = y(xx \cdot z)$	350	64
F_{39} LC ident.	$(y \cdot xx)z = y(x \cdot xz)$	218	33

Continued on next page

F_{40}	$y(xx \cdot z) = y(x \cdot xz)$	923	166
F_{41} LC ident.	$xx \cdot yz = (x \cdot xy)z$	220	47
F_{42}	$xx \cdot yz = (xx \cdot y)\ z$	932	168
F_{43}	$xx \cdot yz = x(x \cdot yz)$	675	119
F_{44}	$xx \cdot yz = x(xy \cdot z)$	295	60
F_{45}	$(x \cdot xy)z = (xx \cdot y)z$	911	165
F_{46} LC ident.	$(x \cdot xy)z = x(x \cdot yz)$	377	76
F_{47}	$(x \cdot xy)z = x(xy \cdot z)$	323	59
F_{48} LC ident.	$(xx \cdot y)z = x(x \cdot yz)$	194	39
F_{49}	$(xx \cdot y)z = x(xy \cdot z)$	242	49
F_{50}	$x(x \cdot yz) = x(xy \cdot z)$	736	132
F_{51}	$yz \cdot xx = (yz \cdot x)x$	675	118
F_{52}	$yz \cdot xx = (y \cdot z\ x)x$	295	55
F_{53} RC ident.	$yz \cdot xx = y(zx \cdot x)$	220	41
F_{54}	$yz \cdot xx = y(z \cdot xx)$	932	210
F_{55}	$(yz \cdot x)x = (y \cdot zx)x$	736	128
F_{56} RC ident.	$(yz \cdot x)x = y(zx \cdot x)$	377	78
F_{57} RC ident.	$(yz \cdot x)x = y(z \cdot xx)$	194	42
F_{58}	$(y \cdot zx)x = y(zx \cdot x)$	323	58
F_{59}	$(y \cdot zx)x = y(z \cdot xx)$	242	47
F_{60}	$y(zx \cdot x) = y(z \cdot xx)$	911	158

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Spot the Story. Blending Augmented Reality Storytelling and Social Awareness

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Abstract

Spot the story is a storytelling application that proposes a new motif in the field of Augmented Reality (AR): social education and advocacy. Using 3D models, challenges, games, dialogues, and a dramatic story, we invite the users to step into the shoes of those directly affected by social issues. Besides raising social awareness, the created system aims to allusively promote the ideological foundation of a niche Romanian short film (which inspired our work), given the nowadays premise that, as far as the audience is concerned, interactive technology wins in front of a preset composition. The latter can easily spread among groups of people in terms of plot and ending, without all of them pursuing the same interest to watch the film in detail if lacking any audience engagement perspective. Since (social) involvement is our main objective, the system provides the film's basis with a couple of variables requiring the users to get involved, by setting them according to their own vision of the proposed social topics.

Keywords: Augmented Reality (AR), storytelling, social education.

1 Introduction

The coordinates of the world we live in stand on two main evolutionary axes, blended together in mankind's development: the individual

progress and potential and the social guiding environment that sums up the individual premises alike, giving louder voices to the ones brave enough to release longly silenced ground truths into the world. Taking into account that "fortune favors the bold", we challenge story and movie lovers of all ages to value the vision of a Romanian stage director, Sabin Dorohoi, about lonely children's lives beyond the curtains of their wealthy appearance, in the alternative AR shape of a character-forming experience. Promoting social concepts of great value but also of high emotional impact is not known to be a stable stepping stone out of social or intellectual anonymity. Due to the natural psychological resistance that individuals instinctively arm with to defend against life-changing truths, one who conveys consciousness awakening has to find the right means of expression to put his ideas under thoughtful debate rather than prompt criticism. This is why we came up with an AR application aiming at the purpose of interacting with core moral concepts in a veiled but wise manner. The story seed of the AR user-oriented experience we created resides in the psychological layer of "Way of the Danube" niche Romanian short film, which was released in two parts in 2013 and 2017 respectively, the second episode being also known as "The Birthday Boy" [1, 2]. Moreover, we considered it appropriate to integrate as soundtrack the "All Over Again" musical piece, which the Voltaj Romanian band performed in the Eurovision Song Contest, edition 2015; this song was meant to contour the red line of the film through musical lyrics and can be seen as a sensitive solution to sharing the concern of a morally and ethically approachable issue, just like our software initiative.

The key components of the AR storytelling experience question the player's own vision on the matter through entertaining tasks, while putting together pieces of the story and targeting a possible reunion between the main character – a 10-year-old boy – and his parents working abroad. Eventually, since free will is placed on the cutting board as the root of our raising awareness initiative, the user makes choices of his own out of many interactive possibilities, which reflects on the invitation we address the user to design his own alternative, heteroge-

neously AR: "*We set up the lights and camera, you customize the action. Ready? Lights, camera, action!*". Going through every challenge we designed, the users gain many meaningful life lessons on various social topics (see Section 5 for the lessons being highlighted according to each challenge). This experience teaches them to treasure every moment life offers, to deeply value the support of family members who remain a constant presence, and to understand that at times, it's necessary to make compromises and sacrifices to pursue their deepest desires and aspirations.

2 Similar products. Our innovative approach

The demand for AR applications is on the rise if we take a look at the evolution of the AR market in the last few years. From $3.5 billion in 2020, AR applications are expected to bring about $72.7 billion by 2024 [3]. This growth is boosted by several factors: the advancements in technology, the increased usage in various industries, the rise in consumer demand for immersive experiences, and not the least, the COVID-19 pandemic. The hardware and software technologies needed for AR have progressed, making it more accessible and immersive. Most of the last generation smartphones support AR and several dedicated products like AR glasses come at attractive prices [4]. The tech giants Google and Apple have dedicated tools for developers who want to create AR applications for mobile devices. Although it started mostly as an enhancement for entertainment applications, today AR is used in multiple domains like education [5, 6], gaming [7], gastronomy [8, 9], and culture [10]. The younger generation craves more immersive and interactive experiences which can be easily achieved using AR. During the pandemic, the need for virtual social connection, remote work, and learning has also relied on AR solutions. Some of the applications that follow the model of blending storytelling and user interaction are:

Story Box AR[1] is an educational AR application designed to be

[1] `https://www.facebook.com/StoryBoxAR/`

used in class or at home by children in order to enhance their story time. Transforming the 2D images from the books into 3D interactive models helps children not only to listen to stories but also to interact with the characters, building their creativity and imagination.

Eternals: AR Story Experience[2] is an application that allows users to experience the Marvel Universe in an immersive way. The fans of superheroes can have a unique interactive narrative experience exploring the Eternals' world, learning about their stories, and their powers, and watching simulated battles. In our app we approach a social theme and we put effort in making the user a part of the plot.

The Last Light[3] is an AR narrative application that tells the story of a young woman who travels home to deal with a difficult family situation, reliving childhood memories on her journey. It uses hand gestures and device controls allowing you to interact with the story in the comfort of your room. In our app we add some more interactivity with speech and object recognition.

Knightfall^{TM} AR is an application that transforms history into a game, and reality into a medieval battlefield. The users have an engaging experience placing siege towers, templar knights, and castles in their environment. This way learning history becomes very tangible and interactive, thanks to the detailed historical events, characters, and battles grasped by the players in a novel way.

Color Quest AR[4] is a health education app designed to teach children about healthy eating and exercise habits. Using amusing food-like animated characters or exercise-themed ones, this application invites children to color and interact with them, and most importantly learn from them about a healthy way of life. In our app we also try to raise awareness, but for a social issue, and we target a broader audience. Besides coloring objects in AR, *Spot the story* has more interactive challenges for the player. As we can see, the available AR applications

[2] `https://www.marvel.com/eternalsar`

[3] `https://world.magicleap.com/en-us/details/com.magicleapstudios.lastlight`

[4] `https://appadvice.com/app/color-quest-ar/1435974934`

that combine storytelling with interactive user experience are tackling educational or entertaining subjects. But we think that the power of AR can be also put in the service of society by engaging in social problems. That's why, using *Spot the Story*, we want to raise awareness of the harsh situation the children left with their grandparents by their work-emigrating parents in Romania.

Despite the common impression that parents do what is right to do, earning the money that the family needs, through our app, we are trying to emphasize the dramatic emotional and psychological cost that this endeavor has on the little ones. To make the experience a holistic one, we brought together challenges that demand the intellect, music, and dialogue that touches the soul, and practical quests where objects from reality or hand dexterity are needed. *Spot the Story* combines in a unique way beautiful 3D models, 2D games, and compelling dialogue with a dramatic story of family decay, children's love, and forgiveness.

3 Overview of our solution. The user's journey

The interactive chapters wrap up the story we tell in a gradually unfolding educational perspective and demand for the user to get involved in the narrative logic and play the role of a fine observer and a trustful comrade of the little boy (see Fig. 1).

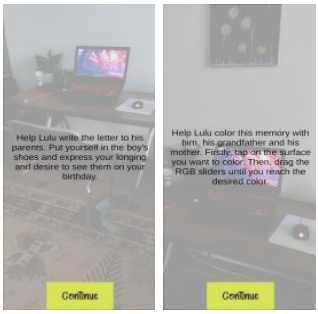

Figure 1. Narrator's instructions

As far as the main features set is concerned, players may decide how the narrative will develop from a certain point, by answering questions via text or voice, by detecting objects or customizing their appearance, and, last but not least, by providing map routes for the desolated child (see Fig. 2 for the modeled environment).

Figure 2. Modelled environment

Players are able to start every chapter by placing the main characters in a spot of their preference from the real, physical environment they stand in at that moment, which explains our choice for the application's title, Spot the Story. To be more precise about the particular challenges requiring the user's attention throughout the chapters, the player's attendance to the story unfolding is, sequentially, subject to a coloring challenge of the content inside an old family glass snow globe (see Fig. 3). This is followed by writing a letter to Lulu's parents via speech-to-text approach; the lack of any response to the letter triggers the need to sum up prices for old things Lulu possesses, in order to gather enough money for a trip to Vienna (see Fig. 3). Furthermore, an Earth globe is to be summoned by a round object from the user's environment and a map route has to be configured to end exactly where the parents' house is located in Vienna (see Fig. 3). Finally, the player reaches the intriguing chapter where, as an immediate consequence of their sudden meeting, Lulu and his parents question the identity of each other, which the user has to clarify through an answer-based game (see Fig. 3). In addition, moving to the next chapter is conditioned by

thoroughly completing the current one. This way, players will be able to build the story piece by piece, in a variety of surroundings, until they assimilate the whole engaging content and experience all the life lessons that can be inferred by rational or emotional reasoning.

Going into details about the user's journey within the storytelling experience, the player follows the narrator's instructions, among which completing challenges in order for the plot to be completed afterward, by the narrator's and character's actions, brings about insightful causality relations to meditate upon from now on. By proceeding this way until the end of the final chapter, the user uncovers a story centered around a 10-year-old boy, Lulu, who lives with his grandfather, due to his parents providing strong and continuous financial support by working abroad, in Vienna (see Fig. 3).

As the first chapter reveals, he and his best friend, Nina, have faith that their parents will return home for their birthdays as they promised. Despite this, time passes without hearing anything from Mom and Dad, which is why finding out about his grandfather's way of tackling painful feelings' persistence, namely by writing them down, results in influencing Lulu to express the longing and loneliness he feels in a letter and send it to Vienna. To the boy's disappointment and despair, the answer to his letter never came either. Feeling inspired by the traveling adventures grandpa has embarked on in his youth, Lulu gains enough money of his own – by selling those toys he used to receive as gifts instead of mom and dad's presence next to him – and gets to his parent's house in Vienna by boat, right on time to celebrate his birthday. Nightfall surprises Lulu asking difficult unspoken questions, the kind of questions that were kept under his little mind's captivity for too long: "Mom, why didn't you come home in the past seven years?". The mother replies with grown-up apologies and financial explanations the boy couldn't understand through the long-lasting feeling of repeated betrayal he perceives them with. The story closes with mom's image crying upon finding a box filled with money on her bed, along with a note saying "I sold my toys to get money for this trip, but I put aside as much as I could from them, though. Look carefully inside

the box! They are for you and Dad so that you won't have to earn money from abroad anymore and leave me again and again. Sincerely, Lulu…", proving that, in the end, life is all about deep connections and the feeling of belonging.

4 Challenges and Games

Figure 3. Challenges: from the first to the sixth, from left to right

Spot the Story is also designed as an interactive AR game and because of that, the player needs to complete certain challenges along the storyline in order to feel more connected with the main character named Lulu, to empathize with his emotions caused by the absence of his parents and to help him overcome the difficulties encountered on the journey he is about to embark. Each challenge is related to specific moments from Lulu's touching story and offers instructions so that the player understands the context and what he needs to do in order to complete them all. By immersing himself in these challenges, a player is not only entertained but also actively engaged in the way the boy's adventure unfolds. Each completed challenge contributes to the player's learned life lessons.

The *first challenge* consists of coloring a 3D portrait of Lulu's family which includes him, his mother, who together with the boy's father left him home to go work in Vienna and earn money, and his grandfather,

the person who raised him and with whom he lives. The player receives instructions that tell him to choose a plane surface where the portrait will be placed and that he can color a certain part of the picture by tapping on it and using three RGB sliders to create the desired color. When a part is selected to be colored it will be visually represented by being highlighted. The player can select multiple parts of the portrait and deselect one by tapping on it again. This challenge emphasizes to the user the importance of cherishing every life moment, the portrait holding even more sentimental value for Lulu now, since his family is no longer together.

In the *second challenge* the player must help Lulu compose a letter for his parents in Vienna in which he needs to express his longing and great desire for them to come back home for his birthday and never leave. This challenge uses speech recognition to record the player's words and transcribe them on the letter that will be sent out to the parents. Unfortunately, it won't reach them and will be returned to Lulu, but his mom will get the opportunity to read it at the end of the story. By completing this challenge, the user not only learns how to effectively express and communicate their emotions but also develops a deeper understanding of the importance of doing so in a healthy and constructive manner, enhancing their interpersonal relationships and emotional well-being.

The *third challenge* involves the player locating a spherical object within his real-world surroundings that once detected by the device's camera will be replaced with a virtual earth globe and the tales of Lulu's grandfather about his travels around the world will begin to be narrated. The purpose behind this challenge is to uplift Lulu's spirits in the middle of the disappointment caused by the fact that his letter has not been received by his parents. Because of this event and what his grandfather had shared with him, Lulu decides to put together his own plan to go find and see them in Vienna. When the user observes Lulu's unwavering support from his grandfather, always there to offer guidance, it serves as a powerful reminder of the vital role that a united family plays in everyone's lives. This portrayal underlines the enduring

truth that family remains a constant presence, ready to provide help when it's needed, reinforcing the unbreakable bonds of love and care within the family.

In the *fourth challenge* the player must help Lulu accomplish his plan by selling some of his toys in order to raise money for the trip. The toys are placed all over the boy's room and each one has an associated price. The player can select a toy by tapping on it, and once he does so, the amount of money raised will increase along with the number of toys sold. The player successfully passes this challenge only if he reaches the requested amount of money by selling the minimum number of toys. The idea of this task was inspired by the discrete knapsack problem. By engaging in this challenge, the player contributes to Lulu's quest, develops his problem-solving skills and decision-making abilities, and also learns that family comes first, and the desire to be with them can overcome any obstacle that may stand in one's way. This new insight emphasizes to the user how important it is to make sacrifices when needed, showing the extent to which someone will go to prioritize their family bonds and connections.

The *fifth challenge* consists in creating the route Lulu must follow to arrive in Vienna so he can be reunited with his parents. There are multiple similar levels, each one being associated with a city through which the boy must pass. In a level are several cities available for the player to choose from but only one of them is the correct choice for the next destination. The player has to draw on the screen the path on which the ball representing the Earth globe will slide onto the targeted city. If it is not the correct one, then the player is notified with a message and will have to try again until he succeeds. This challenge creatively engages the user's general knowledge, transforming a simple task into an enjoyable and educational experience.

The *last challenge* is inspired by game theory. It introduces two strategies for the parents – whether or not to follow the instinct regarding the resemblance between Lulu and their long-abandoned child - and two for the child – whether or not to confess his identity to them. Over several successive rounds, the child will make choices (via the

player) with the goal of being recognized by his parents. In Table 1, the strategy used is detailed: If both the parents and the player admit, then each party is rewarded with a score of +2 points. If the player admits but the parents don't, then the player takes -1 points, and the parents gain +3 points. The same scoring scheme applies if the parents admit and the player does not. And if neither of them admits, then the score does not change.

Table 1. Strategy representation

Child \ Parents	Admit	Deny
Admit	+2 / +2	+3 / -1
Deny	-1 / +3	0 / 0

The player must accumulate a minimum of 15 points in order to successfully complete this challenge and reunite the family. This challenge stands out as the user is placed in a more difficult situation. However, it teaches him a vital lesson: rebuilding relationships demands time, trust, and patience.

5 Conclusion

Spot the Story could be further developed especially in the design and graphics. We could use a more uniform look and feel. AR applications really need computer graphics and design specialists in order to raise the usability of the app and the overall aesthetic impression. Also, the dialogues could be better recorded in a professional studio. And not the least to say, although intensively tested on mobile phones, our app could use some testing on some advanced devices like AR glasses. The future of AR applications will be shaped both by user demand and by tech giants' investments. As things stand now, Meta, Apple,

Google, and Microsoft are heavily investing in AR and VR, which will lead to more sophisticated AR glasses and the integration of Artificial Intelligence and the Internet of Things with such devices [11]. This will make the user experience more complex, immersive, interactive, and entertaining. As software developers, we should take advantage of this new field and foster its capabilities in the service of education, health, industry, security, and entertainment.

Despite all these exciting perspectives, we must not forget the social and ethical role that AR applications can have, bringing to user attention social problems like the one Spot the Story presents. AR applications have the unique potential to shed light on social issues in an engaging and interactive way. By providing an immersive, first-hand experience of the trials faced by the characters, AR applications like Spot the Story can effectively stimulate empathy and awareness about pressing societal problems such as labor emigration and its impact on families. Rather than merely presenting statistics or news reports, these apps allow users to literally step into the shoes of those directly affected by the issues, thus creating a personal connection and fostering a deeper understanding of the challenges they face. As participants in the narrative, users are further encouraged to reflect on the consequences of these social phenomena and to consider potential solutions. In this way, AR apps are not just tools for entertainment, but also powerful platforms for social education and advocacy, leveraging the immersive nature of the technology to foster a more empathetic and socially conscious society.

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On some aspects of medical data quality

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Abstract

This paper examines the specific problem of the quality of medical data of patients when they are hospitalized for treatment through the lens of the general problem of data quality. The need to apply international standards in data quality is discussed, taking into account the specifics of the medical field and the national standards and regulations. This necessity is considered with respect to the problem of medical institutions switching to IT systems with electronic medical records and electronic health records. The specifics of the procedures for filling in the files of hospitalized patients are highlighted.

Keywords: medical data, data quality, medical information systems, electronic medical record, electronic health record.

1 Introduction

The problem of data quality is becoming more and more important in all areas of human activity, even more so in healthcare.

Data quality is not a simple scalar measure; it is defined by several dimensions, which reflect certain aspects with special meanings for different users, depending on the purposes for which the data is examined. Evaluation of the quality of data consists in establishing a value for each dimension by which it is appreciated how an aspect, a characteristic quality, is achieved, that allows understanding or decision-making according to the proposed objective.

In most medical institutions (ambulances, clinics, hospitals, laboratories) the data of patients' medical investigations are collected. Depending on the institution's management system, they are contained

in the databases to which users from those institutions or the network of medical communities have secure access.

The quality of data in medical institutions has two aspects: the first one refers to the implications for the patient (without correct data we cannot expect the correctness of the diagnosis, and, therefore, the treatment process and, ultimately, the patient's health); the second one refers to the efficiency of the institution's management that ensures its functioning adequately to the tasks within the limits of the available sources. In this paper, the first aspect is examined. The impact of poor data quality can affect decision-making on treatment tactics and has a strategic influence on the treatment duration.

One of the most valuable assets in current business, as well as in planning for enterprises and institutions, is data. High-quality data is essential for each individual also. Data quality is naturally an evolving concept.

Understanding what good data means and how it can be measured and improved, if necessary, is quite a difficult problem for several reasons. There are a variety of definitions, and the number of dimensions taken into account differs from one domain to another depending on the context. Also, it depends on the vision of those who manipulate the data and for what purpose the data is applied [1].

Quality properties related to data usefulness are called "dimensions" in the literature on data quality.

A dimension is a measurable property of quality that represents some aspect of data (relevance, accuracy, consistency, etc.) and can be used to judge quality. Thus, some concrete data may be considered of high quality in certain respects according to one set of dimensions and less qualitative according to another set of dimensions. Probably, completeness, if this is not one of the most important dimensions, without which it is impossible to talk about the quality of some data, then this is the most frequently requested and encountered one. ISO 8000 [2] is the generally accepted standard for data quality in businesses and organizations.

In the last decades, in scientific publications and those of practical

applications in management, increased attention is paid to the problem of the quality of data and information in databases. It is an undeniably important fact, but no less important is the quality of the data used in hospitals in the initial period, at the admission of the patient when a local database is formed from the data contained in the referral form from the family doctor and in the examination of the doctor in the admission department.

According to many authors including [2], quality in use is generally considered the degree to which a product or a system can be used by users to achieve objectives with effectiveness, efficiency, lack of risk, and satisfaction in specific contexts of use. The properties of quality in use are classified depending on the specifics of the field of activity through different sets of characteristics, among which the most common are: timeliness, precision, traceability, effectiveness, efficiency, and availability.

The standard ISO/IEC 25010:2011 "Systems and software engineering – Systems and software Quality Requirements and Evaluation (SQuaRE) – System and software quality models" [2] defines:

- A model of quality in use and interaction of the product in a specific context, applicable to the human-computer system, including the mode of operation of the system.

- A product quality model composed of eight characteristics (which are subdivided into sub-characteristics) that relate to the static properties of software and dynamic properties of the information system.

The features in both models are relevant to both software products and any computer systems in the field. Terminology of characteristics (Accuracy, Completeness, Reliability, Relevance, Timeliness) and sub-characteristics is defined so that to be applied for measuring and evaluating quality (see Table 1). Thus, the set of quality characteristics can be selected for each context and compared if it corresponds to the applied standard.

Table 1. Characteristics of data quality in the ISO standard. Definitions adapted and modified according to [3]

Characteristic of data quality in the ISO standard	**Definition**
Correctness	the degree to which the data correctly represents the true value of the attribute
Completeness	data has values for all attributes expected in a specific usage context
Consistency	the degree to which the data is consistent and free of contradiction with other data
Credibility	the degree to which the data is considered true and credible by the user
Timeliness	the degree to which the data is age-appropriate in a specific context of use
Accessibility	data can be accessed in the context used
Conformity	the degree to which the data complies with the standards or regulations in force at the institution that maintains an information system
Confidentiality	the extent to which data is accessible and interpretable only by authorized users
Efficiency	the degree to which the data can be processed and provide the expected levels of performance
Precision	the degree to which the data is accurate
Traceability	the degree to which data access and changes are ensured
Understanding, comprehension	the degree to which data can be read and interpreted
Availability	the degree to which the data can be accessed
Portability	the degree to which the data allows installation, replacement or migration from one system to another maintaining the existing quality in a specific context of use
Recovery	the degree to which a certain level of operations and data quality is allowed to be maintained and preserved, even in the event of failure

We insistently promote the idea of using the ISO/IEC 25010:2011 standard even for traditional medical records (on paper), because their gradual transition to electronic support is inevitable. Information systems for electronic medical records keeping can ensure the high quality of medical data, their safety, accuracy, reliability, and easy exchange of information between patient and physician.

Nowadays, there is a world tendency of using patients' medical data in different healthcare institutions in electronic format. According to data from The Commonwealth Fund [10], in developed countries, primary care physicians actively use this format in their practice: Australia – 97% of physicians; Canada – 86 %; England, Netherlands, and Norway – 99 %; France and Germany – 88 %, Sweden – 98 %, New Zealand – 100 %, United States – 91 %.

Developing countries show a lower percentage of such use because of the problems in the level of health care and understanding the new technologies and their potential in resolving challenges in the domain [11].

We believe that in view of the transition over time of any system for patient records maintenance to the electronic version, it can be recommended to maintain and use these standards for patient records, a fact that would not require changes in the process of transition to electronic records.

Standard ISO/IEC 25012 [4] defines the data quality model that includes the same 15 characteristics and sub-characteristics from two points of view: inherent, which includes all the intrinsic characteristics, with the potential to explicitly and implicitly conform to the needs under the specified conditions; and dependent on the system, which refers to how data quality is obtained and maintained in an information system under specified conditions.

Decisions accompanying our daily lives should be based on high-quality data, so estimating data quality is a fundamental element in ensuring the relevance of decisions based on the data used. To increase confidence in data-driven decisions, it is necessary to measure and know the quality of the data used with appropriate tools [5].

A wide variety of commercial, open-source, and academic data quality tools have been developed based on scientific research. The range of functions offered by these tools varies widely, as the term "data quality" is context-dependent and not always used consistently.

Some tools exclusively offer data cleaning and enhancement functionalities that specifically address measurement capabilities, i.e., detection of quality issues and, most commonly, automated data modification (e.g., data cleaning). But this is not usually possible in information systems.

According to [8], tools that detect and report data quality problems are needed and a large number (667) are found, of which 50.82% are domain-specific, dedicated to certain types of data. Among the most common services they offer are data profiling, data quality measurement, and continuous data quality monitoring, but these services are applicable only in specific areas.

2 Quality of data included in medical records

In healthcare, in recent years, many countries have transitioned or are in the process of transitioning from paper to digital records by hospitals, doctors' offices, clinics, and health care facilities. In the specialized literature, when talking about medical information systems, sources of data, and information about the patient, as a rule, the terms *electronic medical record* and *electronic health record* are used.

Electronic medical record (EMR) is a digital version of a patient's paper medical record that contains the patient's limited medical history completed mainly by the family doctor and the specialist doctors to whom the patient was referred for diagnosis and treatment. Patients' EMRs are typically owned and completed by primary institutions of specialized medical care, regardless of size. EMRs are not transmitted outside the institution unless the patient is admitted for inpatient treatment.

The electronic health record (EHR) contains patient information from all medical institutions that, over time, have been involved in

patient care.

The EHR can include medical history, vital signs, progress notes, diagnoses, medications, immunization data, allergies, laboratory data, and imaging reports. It may also contain other relevant information such as insurance information and demographics. When talking about health care reform, it is necessary to emphasize the meaningful use of EHR. EHRs are designed as interoperable systems, which allow data from different systems to be accessed and used. Each medical institution can have access to the complete medical history of the patient, even if he was treated by other institutions. So the patient's medical information reaches every specialist, laboratory, or center, to which he calls. The EHR should be a comprehensive source of medical information on the general health status of patients, designed to be accessible by any authorized institution for diagnosis and medical care.

In Moldova, there are some popular EHR implementations and many small EMR medical information systems installed in both private and public hospitals and diagnostic centers [6].

An example of an EHR is the DICOM Network. This is a distributed medical image preprocessing and archiving system.

The DICOM network was launched in Moldova in 2012 with the aim of providing access to collected imaging data for medical personnel with access rights and also access for patients when they need their personal data. Today, the system is implemented in many hospitals in Moldova, collects and processes more than 5 TB of data per month collected from hospitals equipped with different types of medical equipment [7].

Most of these systems contain both the data from the medical records of the patients registered at these medical institutions and also different types of medical image collections. The patient's personal data is the most sensitive and important information that should correspond to the main dimensions of data quality (completeness, correctness, timeliness, accessibility, conformity, etc.) in order to be used with confidence by each medical institution to which the patient has referred, for external consultations, when medical analyzes or images should be transferred to another medical institution, or when the pa-

tient wants to familiarize himself with the analyses and images of his latest investigations. A mandatory condition is securing access to any data and images from the EHR.

In the medical institutions of the Republic of Moldova, personal data is protected by the regulation NCPPD (National Center for the Protection of Personal Data of the Republic of Moldova), which is based on national legislation.

In most hospital institutions, internal standards for maintaining data from patient records are established. For example, in the Timofei Moșneaga Republican Clinical Hospital (Chisinau) in order to standardize data from different departments and to establish a standard method of completing and maintaining the inpatient medical record, the *Standard Operating Procedure* was approved (https://scr.md/page/ro-proceduri-operaionale-269). One can talk about pragmatic quality which refers to how the data enable the medical staff to achieve their goals and how easy to understand, how clear, how usable they are.

This procedure aims to ensure the quality of patient data and, first of all, the correctness and completeness of the medical care process at all stages in order to ensure the quality of the treatment given to the patient during his hospitalization and monitoring.

The most sensitive information present is medical data about patients. Denise Silber [7] finds that more than 86% of eHealth data errors are administrative or process errors: wrong recording of patient information, wrong test orders, and wrong drug prescriptions. The conclusions are based on a study conducted by 42 doctors over a 20-week period in 2000, which highlighted errors that occur outside the hospital setting.

Data quality is an important concern in any application scenario being both frequent and potentially costly. It is estimated that 2% of customer records become obsolete in a month due to data "degradation". Medical centers are plagued by unresolved data quality issues. For medical centers, the most pressing need is to estimate data completeness.

Patients' health can be adversely affected by a lack of documentation on treatments and medications. Other data quality considerations are not to be neglected. These domain-specific problems stem from deficiencies in data management processes or technical restrictions that may also occur in other domains. Data quality, in general, depends on context, that is, on notions of "good" or "poor" data that cannot be separated from the context in which they were produced and used (medical analysis data can be considered good as long as they fall within the limits for each type of analysis, for example, temperature 35-43°C, blood sugar – in the range of 70-120 mg per 100 ml).

3 Some procedures for filling in the records of inpatients

The doctor from the inpatient department, after examining the patient and data from the accompanying documents, enters the *inpatient diagnosis* in the medical record of the inpatient.

Upon inpatient admission, the nurse at the registry completes the inpatient's medical record, in which the *referral diagnosis* is entered according to the referral extract from the outpatient's medical record and the *inpatient diagnosis* (or *Admission Diagnosis* – diagnosis given to patient on admission to hospital).

The attending physician prescribes the exhaustive examination of the patient according to the admission diagnosis, and after the first 72 hours of admission specifies the diagnosis.

The medical record of the inpatient is completed by the staff from different subdivisions of the institution, who fix the information related to the diagnostic process, the dynamic evolution of the pathological process, and the applied treatment. The data in the record are intended to exhaustively reflect the assistance provided, the correctness and completeness of the data about the doctors' prescriptions, and the care provided by the nurses.

Given that the correct diagnosis and care of the patient are directly influenced by the quality of the data in the patient record, we will try to

evaluate at what moments and on whom the quality of the inscriptions in the record depends.

Currently, not all medical institutions maintain patient records in electronic format and there are no databases of medical institutions connected in a functional national network.

However, it is imperative to take into account the ISO/IEC 25010 standard that replaced ISO/IEC 9126-1:2001 and was developed to maintain the quality and evaluation process of the IT product. The standard includes a quality model in use composed of five characteristics (effectiveness, efficiency, satisfaction, freedom from risk, and context coverage) and a quality model defined by the ISO/IEC 25012 standard which includes 15 characteristics valid for any field. We will operate with only those specific to inpatient records for specifying, measuring, and evaluating quality.

Although the scope of the product quality model is for IT systems, many of the characteristics are also relevant to wider systems and services.

The first step in completing the inpatient record is to enter the *referral diagnosis* and *admission diagnosis*.

That is why the data used to argue the referral diagnosis will be checked in terms of validity (if the defined parameters are according to the format of the given hospital and fall within the time interval in which the analyses are considered current), completeness (if they are sufficient to give credibility to the referral diagnosis), accuracy/ up-to-date (if they are not older than 3 days, so they can be used), compliance (the standards or regulations in force regarding the specific context of the case are respected), correctness (the data correctly represent the value of the attributes what confirms the diagnosis) and credibility (the degree to which the staff trusts the included data and reflects the doctor's needs in establishing the diagnosis).

For admission diagnosis, compliance is checked. The data included in the patient record are those that allow the attending physician to initiate the treatment process and prescribe his examination according to the protocol.

The analyses data and the attending physician's own observations lead to specifying the patient's diagnosis based on which the treatment continues.

Since the attending physician acts according to the protocol, and all investigations including analyses are carried out following the internal regulations of the hospital, the problem of trust in the quality of the data used to specify the diagnosis and the treatment of the patient becomes less acute. However, in order to ensure traceability and interoperability of the system and compliance with all the compartments of the ISO 8000 standard, it is necessary to monitor the elements that characterize such dimensions as accuracy, promptness, conformity, and completeness.

4 Conclusions

In this article, the problem of the quality of medical data was examined with the aim of facilitating the transition process to integrated health data systems that would provide the possibility for the attending physician to dispose of all the necessary medical investigations of the patient regardless of the location and the medical unit (laboratory, clinic) at which they were performed.

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An optimal control problem for a modified $M/G/k$ queueing system

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Abstract

Assume that in the $M/G/k$ queueing model, it is possible to choose the number of servers who are working at the beginning of any service period. Suppose that the system starts at time t_0 and that there are then $k + l$ customers waiting for service. We want to determine the optimal number of servers that should be used to reduce the total number of customers to $k + r$, where $0 \leq r < l$, taking the control costs into account. The particular case when the service time is deterministic is treated.

Keywords: Homing problem, stochastic control, $M/M/k/c$ queueing system, first-passage time.

1 Introduction

In the $M/G/k$ queueing model, it is assumed that customers arrive according to a Poisson process with rate λ. They are served, one at a time, by one of the k servers. The service time is a general random variable S for each server, and the capacity of the system is given by $c \in \mathbb{N}$.

In [4], the authors assumed that S was an exponential random variable with parameter μ and that c was finite, so that the $M/G/k$ model becomes the $M/M/k/c$ queueing system. Moreover, they supposed that it was possible to decide how many servers were used at any time instant.

We denote by $X(t)$ the total number of customers in the system at time t, and by $n(t) \in \{1, \ldots, k\}$ the number of servers working at that time instant.

Suppose that, at time t_0, there are $k+l$, where $l \geq 1$, customers in the system and that they are all waiting for service. Let us define the *first-passage time* $T(t_0, l)$ $(= T(t_0, t_1, l, r)$, to be precise) as follows:

$$T(t_0, l) = \inf\{t > t_0 : X(t) = k+r \text{ or } t = t_1 (> t_0) \mid X(t_0) = k+l\}, \quad (1)$$

where $0 \leq r < l$.

The authors considered the following optimal control problem: determine the value of $n(t)$ (which is the control variable) to minimize the expected value of the cost (or reward) function

$$J(t_0, l) := \int_{t_0}^{T(t_0,l)} \{q_0\, n(t) - m[n(t)]\}\, \mathrm{d}t, \quad (2)$$

where $q_0 > 0$ is a constant and $m[n(t)]$ gives the money earned by the system, per unit time, when $n(t)$ servers are working. This problem is an extension of *homing problems*, which were defined for n-dimensional diffusion processes by Whittle [6], to queueing systems; see also Lefebvre and Pazhoheshfar [3]. Whittle [7] considered the case when the cost criterion is risk-sensitive. Other papers on homing problems are the ones by Kuhn [2], Makasu [5], and Kounta and Dawson [1].

To solve the above problem, the authors used *dynamic programming*. We define the value function $F(t_0, l)$ as follows:

$$F(t_0, l) := \inf_{\substack{n(t) \\ t \in [t_0, T)}} E[J(t_0, l)]. \quad (3)$$

This function satisfies the boundary condition $F(t_0, l) = 0$ if $l \leq r$. Moreover, they assumed that

$$F(t_0, l) = F_1 > 0 \quad \text{if } T(t_0, l) = t_1. \quad (4)$$

The following proposition was proved.

Proposition 1.1. *Let $\eta = n(t_0)$. The value function $F(t_0, l)$ satisfies the* dynamic programming equation

$$-\frac{\partial}{\partial t_0}F(t_0,l) = \inf_{\eta}\{q_0\eta - m(\eta) + F(t_0,l+1)\lambda + F(t_0,l-1)\eta\mu - F(t_0,l)(\lambda+\eta\mu)\}, \tag{5}$$

subject to the boundary conditions

$$F(t_0,l) = \begin{cases} 0 & \text{if } l \le r, \\ F_1 & \text{if } t_0 = t_1. \end{cases} \tag{6}$$

Finally, two particular problems were solved explicitly and exactly.

In the present paper, we assume that the service time S is not exponentially distributed. We will treat the case when S is a constant.

2 The case when the service time is a constant

To obtain the dynamic programming equation (5), the authors used the fact that when the service time S has an exponential distribution with parameter μ, then the time D needed for a customer to depart the system after time t_0 has an $\mathrm{Exp}(\eta\mu)$ distribution, so that

$$P[D \le \Delta t] = \eta\mu\Delta t + o(\Delta t). \tag{7}$$

In the $M/G/k/c$ model, this generally *does not* hold.

In this paper, we consider the case when $S \equiv \sigma$, where $\sigma < 1$ and $t_0 + \sigma < t_1$. Moreover, we assume that

- A_1: it is possible to choose the number of servers who are working *at the beginning of any service period.*
- A_2: if it is possible to reduce $X(t)$ to $j \le k+r$ immediately, then the optimizer does it.

The dynamic programming equation satisfied (approximately) by the value function $F(t_0, l)$ will be determined. The special case when $k + l = c$ will be considered and examples to illustrate the results will be presented.

2.1 Dynamic programming equation

Let $N_A(\sigma)$ denote the number of arrivals in the system in the interval $(t_0, t_0+\sigma]$. Notice that $X(t)$ cannot decrease before time σ. We can write that

$$F(t_0,l) = \inf_{\substack{n(t)\\ t\in[t_0,T)}} \left\{ \sum_{\nu=0}^{\infty} E\left[J(t_0,l) \mid N_A(\sigma)=\nu\right] P[N_A(\sigma)=\nu] \right\}. \tag{8}$$

When the capacity of the system is finite, the above equation becomes

$$F(t_0,l) = \inf_{\substack{n(t)\\ t\in[t_0,T)}} \left\{ \sum_{\nu=0}^{c_p-k-l} E\left[J(t_0,l) \mid N_A(\sigma)=\nu\right] \times P[N_A(\sigma)=\nu \mid N_A(\sigma)\le c_p-k-l] \right\}. \tag{9}$$

We have, making use of Bellman's principle of optimality,

$$F(t_0,l) \approx \inf_{\substack{n(t)\\ t\in[t_0,t_0+\sigma]}} \left\{ \sum_{\nu=0}^{c_p-k-l} \left[\int_{t_0}^{t_0+\sigma} \{q_0\, n(t) - m[n(t)]\}\,\mathrm{d}t + F(t_0+\sigma, l-n(t_0)+\nu) \right] \frac{P[N_A(\sigma)=\nu]}{P[N_A(\sigma)\le c_p-k-l]} \right\}, \tag{10}$$

where we used the fact that, by Assumption A_1, $n(t)\equiv n(t_0) := \eta$ in the interval $[t_0, t_0+\sigma]$.

Next,

$$F(t_0,l) \approx \inf_{\eta} \left\{ \sum_{\nu=0}^{c_p-k-l} \left[[q_0\,\eta - m(\eta)]\sigma + F(t_0+\sigma, l-\eta+\nu) \right] \times \frac{\frac{(\lambda\sigma)^\nu}{\nu!}}{\sum_{\alpha=0}^{c_p-k-l} \frac{(\lambda\sigma)^\alpha}{\alpha!}} \right\}. \tag{11}$$

Finally, we deduce from Taylor formula that

$$F(t_0+\sigma,\cdot) = F(t_0,\cdot) + \sigma F'(t_0,\cdot) + o(\sigma). \tag{12}$$

Hence, if σ is small enough, we obtain the following proposition.

Proposition 2.1. *The value function $F(t_0,l)$ satisfies the (approximate) dynamic programming equation*

$$\begin{aligned} F(t_0,l) \;\approx\; \inf_{\eta}\Bigg\{ \sum_{\nu=0}^{c_p-k-l} \Bigg[& [q_0\eta - m(\eta)]\sigma + F(t_0, l-\eta+\nu) \\ & + \sigma \frac{\partial}{\partial t_0} F(t_0, l-\eta+\nu)\Bigg] \times \frac{\frac{(\lambda\sigma)^\nu}{\nu!}}{\sum_{\alpha=0}^{c_p-k-l}\frac{(\lambda\sigma)^\alpha}{\alpha!}} \Bigg\}. \end{aligned} \tag{13}$$

The equation is subject to the boundary conditions in (6). Furthermore, because of Assumption A_2, the function $F(t_0, l-\eta+\nu)$ is equal to zero if $l-\eta+\nu \le r$.

2.2 The case when $k+l=c_p$

When $k+l=c_p$, Eq. (13) reduces to

$$F(t_0,l) \approx \inf_{\eta}\left\{ [q_0\eta - m(\eta)]\sigma + F(t_0,l-\eta) + \sigma\frac{\partial}{\partial t_0}F(t_0,l-\eta)\right\}. \tag{14}$$

Remarks. (i) The above equation does not depend on the parameter λ. This is due to the fact that there cannot be any arrivals in the system in the interval $[t_0, t_0+\sigma]$.

(ii) Moreover, if $l-\eta \le r$, Eq. (14) is simply

$$F(t_0,l) = \inf_{\eta}\left\{ [q_0\eta - m(\eta)]\sigma \right\}. \tag{15}$$

Notice that the above equation is *exact*, and not only approximate, because we actually do not have to use dynamic programming to derive it.

We will now present two examples for which the optimal control will be obtained.

2.2.1 Example 1

The simplest case possible is the one for which $k = 2$, $l = 1$, $r = 0$, and $c_p = 3$. The optimizer must then choose either $n(t_0) = 1$, or $n(t_0) = 2$. Because $k + l = c_p$ and $l - \eta \leq r$, we can consider Eq. (15) to determine the optimal control.

Assume that the function $m[n(t)]$ is given by $m[n(t)] = \gamma n(t)$, where $0 < \gamma < q_0$. We have

$$F(t_0, l) = (q_0 - \gamma)\sigma \min_{\eta}\{\eta\}. \tag{16}$$

Therefore the optimal solution is to choose $n(t_0) = 1$.

2.2.2 Example 2

Suppose now that $l = 2$ in Example 1. Let $E_i(t_0, l)$ denote the expected value of the cost function $J(t_0, l)$ if the optimizer chooses $n(t_0) = i$, for $i = 1, 2$, and let $\kappa := q_0 - \gamma > 0$.

If we take $n(t_0) = 2$, there will be two customers left in the system at time $t_0 + \sigma$, so that

$$E_2(t_0, l) = 2\kappa\sigma, \tag{17}$$

as in Example 1.

However, if we take $n(t_0) = 1$, there will be three customers in the system at time $t_0 + \sigma$. It follows that

$$E_1(t_0, l) = \begin{cases} 2\kappa\sigma & \text{if } t_0 + 2\sigma < t_1, \\ \kappa\sigma + F_1 & \text{if } t_0 + 2\sigma \geq t_1. \end{cases} \tag{18}$$

Thus, we may conclude that the optimal control is given by

$$n^*(t_0) = \begin{cases} 1 \text{ or } 2 & \text{if } t_0 + 2\sigma < t_1, \\ 1 & \text{if } t_0 + 2\sigma \geq t_1 \text{ and } F_1 \leq \kappa\sigma, \\ 2 & \text{if } t_0 + 2\sigma \geq t_1 \text{ and } F_1 \geq \kappa\sigma. \end{cases} \tag{19}$$

3 Conclusion

In this paper, a homing problem for a modified $M/G/k/c$ queueing model was considered. We treated the case when the service time S is a constant σ. We derived the approximate dynamic programming equation satisfied by the value function $F(t_0, l)$.

In the special case, when the number of customers in the system at time t_0 is exactly equal to the system capacity, the equation satisfied by $F(t_0, l)$ is exact. We presented two examples in which we determined the optimal control $n^*(t_0)$.

Next, we could try to obtain the optimal control when we must solve Eq. (14) or Eq. (15). To do so, we can proceed as in [4].

Finally, we could also try to obtain the optimal control when the service time is a random variable for which Eq. (7) is not satisfied, for instance in the important case when S has a gamma distribution $\mathrm{G}(\alpha, \lambda)$ (with $\alpha \neq 1$, so that it is not an exponential distribution).

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Integrating Modern Technology into Scientific Research: Harnessing Ensemble Methods and High-Level Algorithms

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Abstract

This article elucidates the profound impact of modern technological advancements on scientific research, emphasizing the transformative role played by ensemble methods and high-level algorithms. By harnessing these sophisticated computational techniques, researchers can unlock deeper insights from intricate data, streamline experimental processes, and expedite the pace of discovery. The exploration spans the principles, applications, and future potentials of integrating ensemble methods and high-level algorithms into scientific inquiry, with a spotlight on their revolutionary capacity. The practical application of these techniques is exemplified through the analysis of the "Smoker Status Prediction" dataset and the consequential prediction of hemoglobin levels, underscoring their compelling relevance in contemporary scientific research.

Keywords: Modern technology, Scientific research, Ensemble methods, Computational techniques, Data analysis, Research optimization.

1. Introduction

In recent decades, the world has witnessed a remarkable convergence of technology and scientific research, ushering in an era of unique possibilities and opportunities for innovation. Evidently, the burgeoning scale and intricacy of contemporary scientific datasets necessitate a

paradigm shift toward the deployment of sophisticated computational methodologies. Traditional modalities of analysis and interpretation often find themselves ill-equipped to discern salient patterns within these voluminous and intricate datasets. At the forefront of this technological revolution are ensemble methods and high-level algorithms, which have emerged as pivotal components in the arsenal of modern scientists [1].

Ensemble methods, a diverse cadre encompassing an array of algorithmic techniques, are strategically formulated to augment predictive accuracy and bolster model resilience by virtue of the judicious amalgamation of output from multiple constituent algorithms or models [2]. High-level algorithms, on the other hand, offer a sophisticated approach to data analysis and problem-solving, providing researchers with the computational power needed to tackle complex research questions [3]. These two components are not only transforming the way scientific research is conducted but also accelerating the pace of discovery across a wide spectrum of disciplines [4]. Ensemble methods and high-level algorithms empower researchers to navigate through the vast amount of data, enabling them to uncover hidden patterns, make accurate predictions, and optimize experimental processes [5].

The ensuing paper undertakes a comprehensive exploration of the impact wrought by ensemble methods and high-level algorithms within the precincts of scientific research. In so doing, it endeavors to illuminate their theoretical underpinnings, multifarious applications, and their potential to substantively remold the scientific milieu.

In the following sections, we will analyze ensemble methods and high-level algorithms, examining their roles, advantages, challenges, and applications in driving scientific progress.

2. Ensemble Methods: A Comprehensive Overview

Ensemble methods are algorithmic constructs characterized by their principle of amalgamating predictions from a multitude of constituent models or algorithms. They harness the knowledge of the majority, synthesizing diverse insights to achieve superior predictive accuracy and robustness.

Within the purview of ensemble methods, several distinct categories emerge, including but not limited to bagging, boosting, stacking, and

random forest [6]. Each category embodies unique methodologies and nuances, tailored to specific problem domains and data characteristics.

The advantages inherent to ensemble techniques are multifarious and profound. Foremost among these is the fortification of model stability through the reduction of variance and the mitigation of overfitting, a perennial concern in the realm of scientific modeling.

Furthermore, ensemble methods confer the capacity to ameliorate model generalization by harnessing the collective predictive wisdom of multiple constituent models. This bolsters predictive performance and furnishes a more accurate reflection of the underlying data structure.

In scientific data analysis, ensemble methods wield transformative potential. By aggregating diverse modeling perspectives, these techniques enable researchers to extract latent patterns, mitigate noise, and ultimately unearth elusive insights concealed within complex datasets.

Illustrative of the impact engendered by ensemble methods are a myriad of success stories across the scientific spectrum. In the domain of genomics, for instance, ensemble methods have been instrumental in deciphering intricate gene expression patterns and predicting genetic predispositions with unparalleled precision [7].

In climate science, ensemble techniques have ushered forth-groundbreaking advancements, allowing for the development of predictive models capable of simulating complex climatic phenomena and elucidating the nuanced dynamics of climate change [8].

The realm of material science, likewise, has borne witness to the expedited discovery and design of novel materials through the judicious application of ensemble methods, enabling researchers to optimize material properties with high efficiency [9].

In the healthcare and pharmaceutical domains, ensemble methods have galvanized personalized medicine initiatives, offering the capacity to tailor treatment regimens to individual patient profiles and facilitating drug discovery through predictive modeling of molecular interactions [10].

The synthesis of these exemplars underscores the pivotal role ensemble methods play in scientific research, elucidating their efficacy in enhancing data-driven discoveries, predictive modeling, and problem-solving across multifarious scientific disciplines.

3. Technical examples

Analyzing the "Smoker Status Prediction" dataset and predicting hemoglobin levels is a practical and relevant application of ensemble methods and high-level algorithms in scientific research for several compelling reasons [11]:

- Complexity of Data: Medical datasets, including those related to hemoglobin levels, are typically complex, featuring a multitude of variables and potential confounding factors. Ensemble methods excel in handling such complexity by aggregating insights from multiple models to improve predictive accuracy.
- Data Variability: Health data can exhibit high variability due to factors like genetics, lifestyle, and environmental influences. Ensemble methods, which combine different models, are robust to variability and can provide stable predictions.
- Non-Linearity: Relationships between predictors and hemoglobin levels may be nonlinear. High-level algorithms like Gradient Boosting capture complex, nonlinear patterns in the data, making them suitable for healthcare prediction tasks.
- Accuracy and Generalization: Ensemble methods and high-level algorithms are known for their ability to provide accurate predictions and generalize well to new, unseen data.
- Ensemble of Expertise: Combining multiple models in an ensemble represents an "ensemble of expertise". Each model may excel in different aspects of the prediction task, leading to a more holistic and reliable prediction.

The dataset includes the following health metrics: age, height (cm), weight (kg), waist (cm), eyesight (left), eyesight (right), hearing (left), hearing (right), systolic, relaxation, fasting blood sugar Cholesterol, triglyceride, HDL (cholesterol type), LDL (cholesterol type), hemoglobin, Urine protein, serum creatinine, AST (glutamic oxaloacetic transaminase type), ALT (glutamic oxaloacetic transaminase type), Gtp, dental caries. With 38,985 rows of data, we have a substantial amount of data for training and evaluating machine learning models. This size allows for a

more robust analysis and potentially better generalization of the model. These features encompass demographic information (age, height, weight), biometric measurements (waist circumference, blood pressure), sensory data (eyesight, hearing), and various biochemical markers (blood sugar, cholesterol levels, etc.). The motivation for choosing this dataset is rooted in the health implications of smoking. Smoking is a major public health concern, and predicting smoking status can aid in identifying individuals at risk and tailoring interventions. The introduction provides context regarding the harmful effects of smoking and the global health impact. The chosen bio-signals, including physical measurements, sensory data, and biochemical markers, are indicative of the individual's health status. The inclusion of such diverse features is an attempt to capture a comprehensive picture of the individual's well-being for the purpose of smoking status prediction.

Data visualization is a crucial step in understanding datasets and gaining insights into the relationships between variables. Here's a simple example of data visualization using Matplotlib and Seaborn (Fig.1).

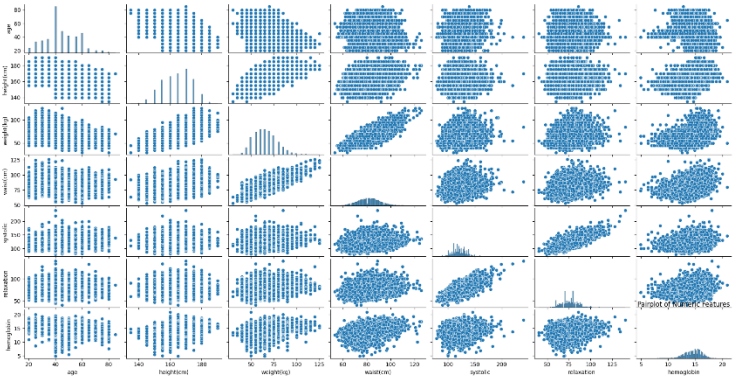

Figure 1. Correlation between numeric features

This plot shows scatter plots of numeric features against each other, including age, height, weight, waist, systolic, relaxation, and hemoglobin. It helps to visualize relationships between variables.

Correlation Matrix Heatmap (Fig. 2) displays the correlation coefficients between all pairs of numeric features. It helps to identify which features are strongly correlated with hemoglobin.

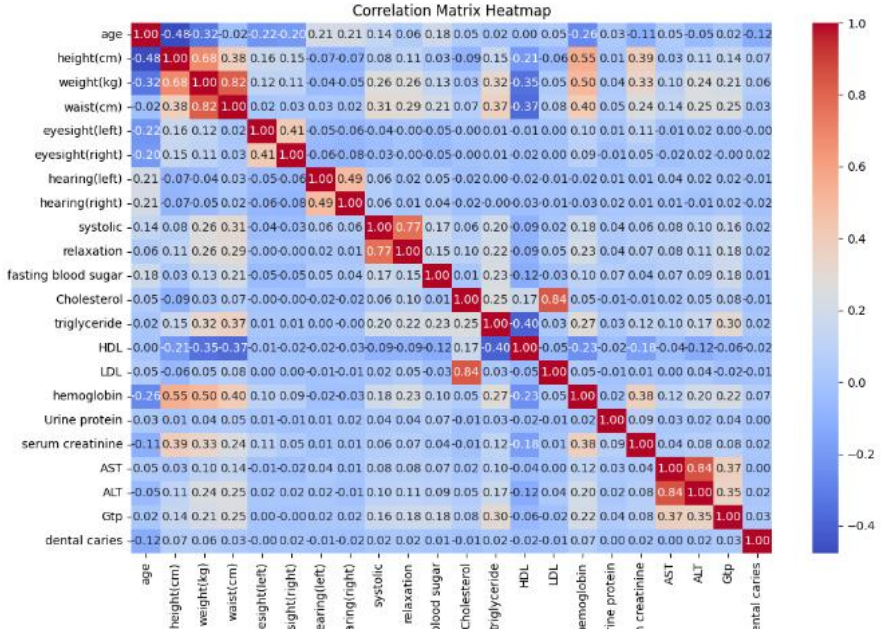

Figure 2. Correlation matrix

The histogram (Fig. 3) shows the distribution of hemoglobin levels in the dataset. It provides insights into the distribution of target variables.

Understanding the relationships and distributions of variables in a dataset is important for several reasons:

1. **Identifying Patterns and Trends**: Pairplots and scatter plots help visually identify patterns and trends in the data. For example, to see if there is a linear or nonlinear relationship between variables.
2. **Feature Selection**: Correlation Matrix Heatmaps are useful for identifying which features are strongly correlated with the target variable (hemoglobin in this case). Features with high correlations may have a significant impact on the target variable and are potential candidates for inclusion in predictive models.
3. **Data Distribution**: Histograms provide insights into the distribution of a variable, in this case, hemoglobin levels.

Deviations from a normal distribution may indicate potential health conditions or outliers in the data.

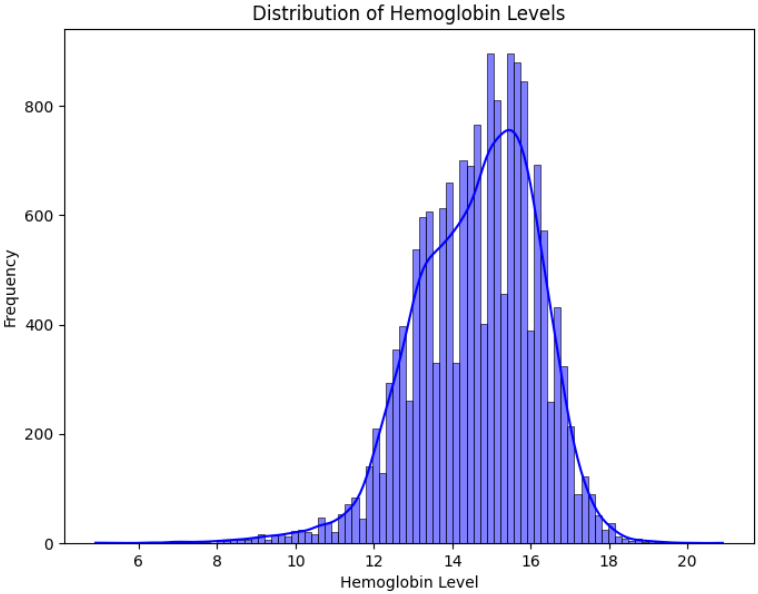

Figure 3. Histogram of hemoglobin distribution

To gain a comprehensive understanding of the dataset's intricacies, an in-depth analysis was conducted. This entailed the exploration of variable distributions, the unraveling of relationships between key attributes, and the scrutiny of data patterns. Visualizations, including graphs and plots, were instrumental in unveiling the dataset's underlying structure, detecting potential correlations, and identifying outliers that might influence our predictions.

To evaluate our models effectively and gauge their performance, we partitioned the dataset into distinct training and testing sets. For training, our model selection encompassed such methods as the Ridge Regression, KNeighborsRegressor, Linear Regression, Decision Tree Regression, author's Ensemble Methods, Random Forest, and Gradient Boosting [12-14].

Leveraging the training dataset, we imbued our models with the capacity to learn and optimize their performance. The evaluation of our models was conducted with the utmost scrutiny. Appropriate regression metrics, including the Mean Squared Error (MSE), or R-squared (R^2), were judiciously applied to assess model performance on the testing dataset (Table 1).

Table 1. Models performance metrics

	Mean Squared Error	R-squared
Ridge Regression	1,42	0,43
KNeighborsRegressor	1,63	0,35
Linear Regression	1,42	0,43
Decision Tree Regression	2,31	0,07
Ensemble Methods	1,339	0,445
Random Forest	1,132	0,546
Gradient Boosting	1,195	0,521

Mean Squared Error (MSE): MSE is a measure of the average squared difference between the predicted values and the actual (observed) values in a regression model. It quantifies the overall accuracy of the model's predictions. A lower MSE indicates better predictive accuracy, with zero being a perfect score.

In Table 1, each model's MSE values are listed. For example, for "Ridge Regression", the MSE is 1.42, indicating that, on average, the squared difference between the predicted and actual values is 1.42. Lower MSE values are generally preferred, as they signify a closer fit to the actual data.

R-squared (R^2): R-squared is a measure of how well the independent variables in a regression model explain the variation in the dependent variable. It ranges from 0 to 1, where 0 indicates that the model doesn't explain any variation, and 1 means that the model perfectly explains all the variation.

In Table 1, R-squared values are provided for each model. For instance, "Ridge Regression" has an R^2 of 0.43, indicating that this model explains 43% of the variation in the dependent variable (hemoglobin

levels). Higher R-squared values are generally desirable, as they signify a better fit of the model to the data.

Based on the analysis of MSE and R^2 values presented in fig. 4, the "Random Forest" ensemble learning method appears to be the best choice among the options, followed by "Gradient Boosting", and "Ensemble Methods". It has the lowest MSE (1.132), indicating better predictive accuracy, and the highest R^2 value (0.546), indicating a good fit to the data.

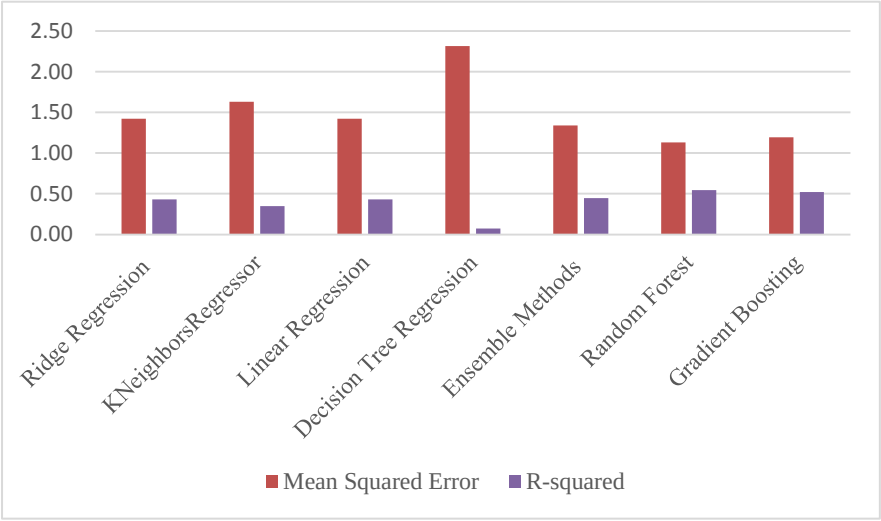

Figure 4. Histogram of model performance metrics

These metrics suggest that the Random Forest model performs well in predicting hemoglobin levels based on the given dataset.

4. Conclusion

In summative reflection, is resoundingly evident that ensemble methods have proven instrumental in elevating predictive accuracy within complex datasets.

Analysis of the "Smoker Status Prediction" dataset, aimed at predicting hemoglobin levels using various regression models, has yielded valuable insights. We considered several regression models and evaluated their performance using two key metrics, Mean Squared Error (MSE) and

R-squared (R^2). The obtained results extend the utility of advanced computational techniques to the realm of public health.

Among the models assessed, the "Random Forest" model emerged as the top performer. It demonstrated the lowest MSE (1.132), signifying superior predictive accuracy, and the highest R^2 (0.546), indicating an excellent fit to the data. These results suggest that the Random Forest model is well suited for predicting hemoglobin levels based on the dataset's features.

Additionally, "Gradient Boosting" and "Ensemble Methods" also delivered a commendable performance, with competitive MSE and R^2 values.

Conversely, models such as "KNeighborsRegressor" and "Decision Tree Regression" exhibited comparatively weaker predictive performance, characterized by higher MSE values and lower R^2 values.

The choice of the most suitable model depends not only on predictive performance but also on other considerations, such as model interpretability, computational complexity, and the specific requirements of the application. This information aids researchers and practitioners in selecting appropriate models for health prediction tasks.

However, further exploration and fine-tuning may be warranted to optimize model performance and address domain-specific nuances.

The results of the research presented in the paper hold significant implications across various domains, offering potential applications that can enhance and streamline different facets of scientific inquiry and related fields. Some potential areas of application include biometrical research. The predictive capabilities of ensemble methods and high-level algorithms can be employed in biomedical research for disease prognosis, patient outcome prediction, and identification of biomarkers. This can contribute to personalized medicine and more effective treatment strategies.

In summary, the strong points of the paper lie in its comprehensive dataset, holistic approach to health assessment, motivation, and relevance, effective use of data visualization, in-depth analysis, and thorough model selection and evaluation. The main contributions of the authors include a novel application in health prediction, insights into model performance,

identification of an optimal model, and the potential for personalized interventions.

As we contemplate the path forward, it becomes evident that the harmonious amalgamation of technology and scientific progress is indispensable.

Embracing technology in scientific research signifies a commitment to harnessing the full potential of computational techniques, data analytics, and algorithmic ingenuity to elucidate the mysteries of the natural world.

Interdisciplinary collaboration, knowledge sharing, and open science practices shall be the keystones upon which future scientific progress is erected.

In this juncture of technological ascendancy, the scientific community stands poised to embark upon a trajectory of important discovery and innovation, propelled by the symbiotic relationship between modern technology and the unrelenting pursuit of knowledge.

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Multi-Agent Coalition Systems for Multi-Goal Decision-Making

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Vadim Struna, Victor Lașco

Abstract

This paper presents the results of designing Multi-Agent systems with applied coalitions for decision-making with Multi-Objective conditions in complex processes. The system is based on interaction and collaboration between several Agents, each of which can evaluate and optimize its objectives by applying Genetic Algorithms. The coalition formation process is defined by the mathematical model, the functionality of which and the interaction between Agents are explained based on the sequence diagram. The result of an example of coalition formation is presented as a topology of interconnection between the set of Agents.

Keywords: Multi-Agent, Collaborative Agents, Coalition Systems, Decision-Making, Multi-Goal, Genetic Algorithms.

1. Introduction

The problem of searching for optimal solutions, defined by complex processes specific to the real world, requires the application of so-called Artificial Intelligence models. As practice shows, it is impossible to select a single technique that will provide the required performance. In the research presented in [1], the authors demonstrate the necessity and efficiency of merging different techniques based on models of Artificial Intelligence (evolutionary algorithms, neural networks, fuzzy logic or hybrids thereof, Bayesian networks, etc.) and traditional models, which present synergy and provide powerful environments for solving complex problems.

Particular cases of the application of Artificial Intelligence are Multi-Agent systems that consolidate modern techniques, technologies, and

knowledge from various fields of science [6-8]. New trends and challenges in agent systems and new research in the field of interaction and collaboration, modeling, simulation, and mobile agents, communication with agencies and social networks, and business informatics, are just a few aspects specific to the development of Multi-Agent systems [2].

The efficiency of a Multi-Agent system can only be achieved if coalitions are formed. It is considered that coalition formation is a fundamental form of interaction that allows the creation of coherent groupings of different, autonomous agents in order to effectively achieve their individual or collective goals. As mentioned in [3], forming effective coalitions is a major research challenge in the field of Multi-Agent systems. This research is geared towards calculating a quality coefficient for each possible coalition, which indicates how beneficial that coalition would be if formed.

Coalition formation [4] is a process by which Agents recognize that cooperation with others can take place in a mutually beneficial manner and therefore Agents can choose appropriate temporary groups (called coalitions) to form. The benefit of each coalition can be measured by the goals it achieves, the tasks it performs, or the utility it gains.

Multi-criteria decision-making is one of the main issues aimed at determining the best alternative in the selection process [6, 9, and 11]. Many tools and methods are developed that can be applied in different fields, from finance to engineering design. Multi-Criteria Decision Making is one of the most accurate decision-making methods and can be known as a revolution in this field [5]. There is more scientific research that has demonstrated the ability to mathematically model these methods to provide a framework that can help structure decision-making problems and generate preferences from alternatives.

In this paper, it is proposed a Multi-Agent system for decision-making with multiple objectives and the ability to self-configure coalitions in relation to the optimization criterion.

2. Statement of Research Problem

The field of activity is defined $D=\{A, X, Y, S, C\}$, where $D \in R^N$ and:

$A = \left\{ A_i, \forall i = \overline{1,I} \right\}$ - is the multitude of Agents who work in the respective field (activities of research and development, production, logic, sales and marketing, customer service, administration, and others), have autonomy and reasoning, and have the ability to perceive, process, learn and act;

$X = \left\{ x_j, \forall j = \overline{1,J} \right\}$ - is the set of controlled parameters that also determine the state of the field of activity D, where $X \subset R^N$;

$Y = \left\{ y_j, \forall j = \overline{1,J} \right\}$ - is the set of action decisions on the field of activity D, where $Y \subset R^N$ and $Y : X \to X$;

$S = \left\{ s_i, \forall i = \overline{1,I} \right\}$ - is the set of strategies (objectives) applied by Agents to achieve their pre-defined target objectives $f(X) \to opt$, where $S : X \to Y$;

$C = \left\{ C_l, \forall l = \overline{1,L} \right\}$ - is the set of coalitions formed by Agents to optimize the calculation process to achieve pre-defined goals $f(X) \to opt$. An Agent may initiate the creation of a coalition by inviting other Agents to collaborate, and respectively, an Agent may participate in more than one coalition by providing information, services, or resources.

3. The mathematical model for the formation of coalitions

The efficiency of decisions generated by the Multi-Agent System depends on the correctness of coalition formation since the time of convergence to the optimal solution directly depends on the number of Agents involved in the calculation process. This efficiency is determined by the parallel organization of the calculation process by the fact that each Agent evaluates the optimization condition only on his personal objective, applying the genetic algorithm in the optimization process [9].

The process of forming coalitions in the Multi-Agent System for Multi-Objective Decision Making with the condition of minimizing the

objective function [10, 11], is defined by the mathematical model presented in (1):

$$A_i \subset C_l^{min} \left| \frac{\partial f\left(X_l\right)}{\partial x_i} \le 0,\ i = \overline{1,I},\ l = \overline{1,L}. \right. \quad (1)$$

In the case of the condition of maximizing the objective function, it is defined by the mathematical model shown in (2):

$$A_i \subset C_l^{max} \left| \frac{\partial f\left(X_l\right)}{\partial x_i} > 0,\ i = \overline{1,I},\ l = \overline{1,L}. \right. \quad (2)$$

3. Sequence diagram for coalition formation

The mode of interaction between the set of Coalition-Forming Agents is shown by the sequence diagram in Figure 1.

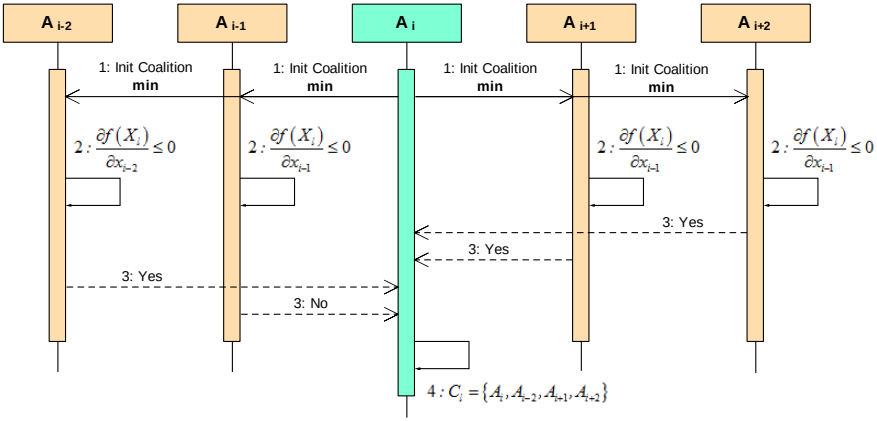

Figure 1. Sequence diagram for coalition formation

The sequence diagram includes:

A_i - The initiating agent for the formation of the coalition;

$A_{i-2}, A_{i-1}, A_{i+1}, A_{i+2}$ - the multitude of Agents involved in the process of assessing the condition of forming the coalition;

1: *Init Coalition* min - Agent A_i sends the message of initiating the minimization coalition to the Agents $A_{i-2}, A_{i-1}, A_{i+1}, A_{i+2}$;

$2: \frac{\partial f(X_i)}{\partial x_{i-1}} \le 0$ - data processing to identify the minimization condition defined by the Agent A_i;

3: *Yes* - the minimization condition is met;

3: *No* - the minimization condition is not met;

$4: C_l = \{A_i, A_{i-2}, A_{i+1}, A_{i+2}\}$ - Agent A_i forms the coalition C_l from the crowd of Agents $\{A_i, A_{i-2}, A_{i+1}, A_{i+2}\}$.

4. Example of coalition formation

Figure 2 shows the result of the formation of 5 coalitions from a crowd of 25 Agents, where:

$A_4, A_7, A_{12}, A_{19}, A_{22}$ - are the Agents that initiated the coalition formation process based on optimization objectives;

Agent A_4 created the coalition $C_4 = \{A_1, A_2, A_3, A_4, A_5, A_6, A_7\}$;

Agent A_7 created the coalition $C_7 = \{A_4, A_5, A_6, A_7, A_8, A_9, A_{10}, A_{11}\}$;

Agent A_{12} created the coalition $C_{12} = \{A_{10}, A_{11}, A_{12}, A_{13}, A_{14}, A_{15}, A_{16}\}$;

Agent A_{19} created the coalition $C_{19} = \{A_{15}, A_{16}, A_{17}, A_{18}, A_{19}, A_{20}, A_{21}, A_{22}\}$;

Agent A_{22} created the coalition $C_{22} = \{A_{19}, A_{20}, A_{21}, A_{22}, A_{23}, A_{24}, A_{25}\}$.

Topological analysis of formed coalitions:

- $C_4 \cap C_7 = \{A_4, A_5, A_6, A_7\}$, $C_4 \cap C_{12} = \varnothing$, $C_4 \cap C_{19} = \varnothing$, $C_4 \cap C_{22} = \varnothing$;
- $C_7 \cap C_{12} = \{A_{10}, A_{11}\}$, $C_7 \cap C_{19} = \varnothing$, $C_7 \cap C_{22} = \varnothing$;

- $C_{12} \bigcap C_{19} = \{A_{15}, A_{16}\}$, $C_{12} \bigcap C_{22} = \varnothing$;
- $C_{19} \bigcap C_{22} = \{A_{19}, A_{20}, A_{21}, A_{22}\}$.

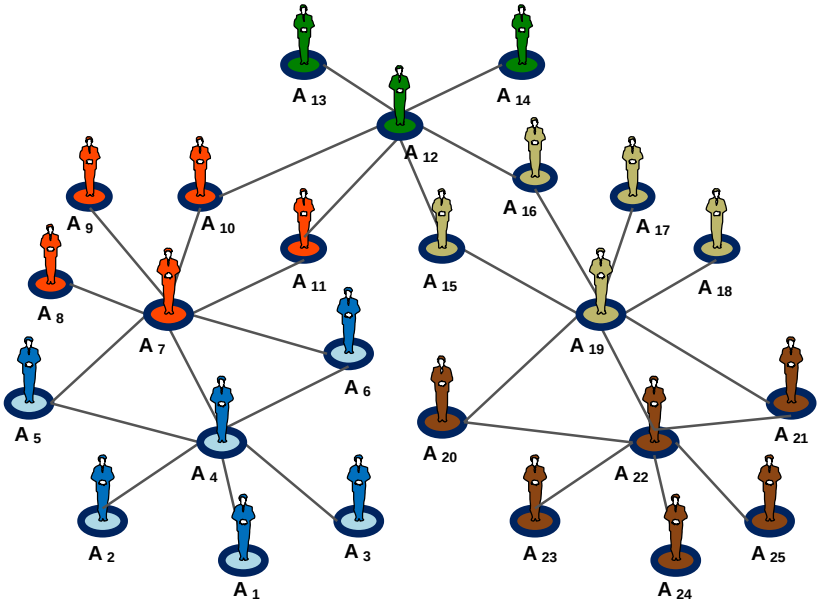

Figure 2. Example of coalition formation

5. Conclusion

More and more modern complex processes apply multi-objective multi-agent architectures as Multi-Objective decision systems. This trend is demonstrated by the fact that these architectures offer the decision-making system an increased capacity to process data, applying simple hardware devices and software products at a reduced price, which have autonomy and use Artificial Intelligence models.

In this paper, it is proposed a collaborative Multi-Agent system for Multi-Objective decision-making. The aim of the paper is to develop the mathematical model that allows Agents to form efficient coalitions and generate optimal decisions in the shortest possible time.

In order to achieve this goal, Genetic Algorithms were used to search for the optimal solution in the space of multiple objectives. The

application of the Multi-Agent architecture allows the calculation process to be organized in parallel, which ensures that the time for data processing is reduced. The process of interaction of Coalition Agents is explained based on the sequence diagram. The result of coalition creation is presented in the form of a topology of interconnection of Agents where their membership in one of the formed coalitions is mentioned.

The scope of the collaborative Multi-Agent system is vast, with potential in areas such as logistics, economics, resource management, or strategic planning. The system's ability to form coalitions allows adaptive decision-making, which leads to increased efficiency and flexibility in the case of changing working environment.

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Different aspects on extractive text summarization as a part of content generation for e-courses

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Abstract

The paper describes automatic summarization as one of the topics that help the e-learning system to be more adaptable to content generation. This article treats automatic summarization with approaches that provide the ability to summarize texts in different languages. In the case of this article, it is about the English, Romanian, and Russian languages. The paper contains both a description of the problem and different approaches already used by other researchers. Next, the data with which the automatic summarization experiments were carried out were described. The metrics with which we can evaluate the quality of the summarization result were presented. Finally, some thoughts were formulated regarding the results obtained in the experiment.

Keywords: e-learning systems, text summarization, evaluation metrics, datasets, data analysis.

1 Introduction

Humanity in the 21st century has made a huge leap in computer science. Chat GPT is the best demonstration of this thesis. It would seem that lots of information on the Internet hampers human work with its variation and validity. Chat GPT has succeeded with this problem and proposed remarkable results. This opportunity throws light on content generation [1].

On the other hand, because of the enormous amount of information daily generated, the manual completion of an e-learning system with appropriate content is a difficult task for every teacher. With these special possibilities of automatic content generation, it becomes an interesting idea to supplement e-learning platforms with a part of this huge amount of information referring to specific topics. In conditions where there is so much information on the Internet, the need to reduce and understand it, in a limited time, becomes important. The processes of text understanding and production are directly related to the creation of summaries. That is why making a consistent summary is an important approach to understanding and selecting the appropriate idea to be included in educational materials on e-learning platforms.

Automatic text summarization is a technique that takes a source text and extracts the most crucial information, condensing it and tailoring it to the demands of the user or job. The source text is first read, and its content is identified. The main points are then collected in a brief summary [2, pp. 2-4].

Searching approaches on automatic summarization, literature review brought us three solutions: *prompt engineering, abstractive-based summarization* and *extraction-based summarization*. The first two consider neural network technology, namely **transformers**. The last one relies on **standard NLP techniques** [3]. In this article, we consider the last solution: extraction-based summarization.

In contrast to abstractive techniques, which conceptualize and paraphrase a summary, extractive techniques accomplish summarization by selecting bits of texts and creating a summary [4].

The **purpose** of this article is to find the way of evaluating text summaries in the first place, to identify the best approach for summarization in the second place, and to investigate whether there are problems from a multilingual perspective in this procedure in the third place.

To achieve the goal of the paper, we will structure the paper as follows. Initially, we will present the data we will work with, namely their type, quantity, and scope. We will continue with the presentation

of the methods and metrics needed to evaluate the experiment and after that, the essence of the experiment and the data obtained will be presented. Finally, we will draw some conclusions based on what we obtained.

2 Experiment description

In order to examine the quality of the extractive summarization, six texts from different sources with different structures and domains of topic were selected (see Table 1).

Table 1. Descriptions of the selected datasets

	Domain	**Language**	**Chars**	**Words**
1	History	English	8599	1309
2	Geography	English	7939	1326
3	Biology	Russian	10323	1356
4	Literature	Russian	53328	6879
5	Informatics	Romanian	20579	3063
6	Law	Romanian	11780	1652

As part of our experiment, we investigated various types of methods for automatic summarization. Some of them are built on plain speculations and others are built on more complicated algorithms. The following summary methods described in paper [5] were investigated:

1. **Luhn's Heuristic Method** – proposes that the **significance of each word** in a document **signifies how important it is**. According to this theory, *sentences that contain more stopwords* (words with the highest frequency), than others *do not have a greater impact* on the document's meaning [10].

2. **Edmundson Heuristic Method** – recommends **the use of a subjectively weighted mixture of features**. He took into account the features that were previously well-known and utilised in Luhn's method, but he also included a few new features such as *cue words* and *document structure* [11].

3. **Latent semantic analysis (LSA)** – is a reliable algebraic-statistical technique that can **find synonyms in the text and subjects that aren't mentioned clearly in the text**. LSA works by *breaking down the data into small, manageable spaces* [2, p. 1002].

4. **SumBasic algorithm** – produces summaries of **length n**, where **n** is the user-specified number of sentences.

5. **Kullback-Lieber (KL) Sum algorithm** – its goal is to identify a set of sentences whose length is fewer than **L words** and whose unigram distribution closely resembles that of the source text [8, pp. 522-523].

6. **Graph-based summarization (Reduction)** – employs a graph to rank the necessary sentences or words in our **unsupervised strategy**. The primary goal of the graphical method is to extract the most significant sentences from a single source.

7. **LexRank algorithm** – is also a method related to graph based approach. It uses the cosine similarity of TF-IDF vectors;

8. **TextRank algorithm** – is also a method related to the graph-based approach. It uses measures based on the number of words two sentences have in common (normalized by the sentences' lengths).

9. **Term Frequency method** – enlightens us as to *which terms are most frequently used* and sheds light on the *significance of particular terms* in a given text or group of papers. The length of each document varies, thus *it is likely that a term will appear more frequently in larger documents* than in shorter ones. In order to normalize term frequency, it is frequently divided by the total number of terms in the document. Other methods of normalizing word frequencies include using the average and maximum term frequencies found in a document.

10. **Term Frequency-Inverse Document Frequency (TF-IDF)** – is a commonly used method in NLP to assess the importance of words in a document or corpus. IDF is a weight that **represents a word's usage volume**. The lower the score, the more frequently it is used throughout documents. A text vectorization procedure converts words in a text document into significance numbers. The TF-IDF vectorization/scoring method, as the name suggests, *multiplies the Term Frequency* (TF) and *Inverse Document Frequency* (IDF) of a word to determine its score [12].

The first eight approaches were applied from the ***Sumy*** library for text summarization. The term frequency method was examined from ***NLTK*** and ***Spacy*** library and TF-IDF approach was examined by ***NLTK*** and ***Scikit-Learn***. Summing up, we have investigated twelve methods for text summaries.

In order to estimate the quality of each method, we used four metrics discussed in [2]:

- ROUGE (ROUGE-1, ROUGE-2, ROUGE-L) – score component provides a unique viewpoint on the effectiveness of the system-generated summary by taking various linguistic and grammatical elements into account [6, p. 74]. It defines *how many words in reference summaries* appeared in the candidate summaries.

- BLEU – is based on the basic idea of comparison machine translations/summarization with those regarded to be accurate by humans. Each segment (mainly sentences) is being compared with a set of qualitative reference texts. The obtained scores are then averaged over the whole corpus to reach an estimate of the translation's/summarization's overall quality [7, p. 394];

- METEOR – overpasses previous metrics, taking into account **grammar and semantics**. The metric is based on the harmonic mean of unigram precision and recall, with recall weighted higher than precision [7, p. 394];

- F-score – also relies on precision and recall, but data are different. Precision represents the **number of sentences** taking place in both summaries divided by the number of sentences in the candidate summary. The basic way how to compute the F-score is to count a harmonic average of precision and recall.

Beyond the upper metrics, we have used the metrics provided by the ***Sumy*** library, which evaluates its own algorithms with ***ROUGE***, ***F-score*** and ***Unit overlap*** metrics.

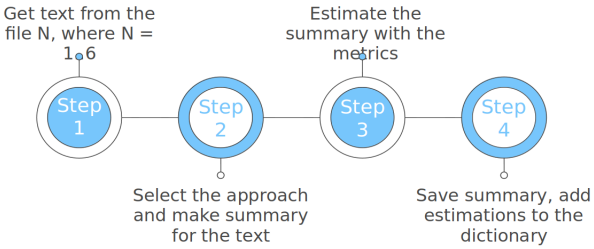

Figure 1. The course of the experiment

The experiment consisted of a process that had two loops: an outside loop for changing texts and an inside loop to change summary methods. At the end of the inner loop, all metrics were taken (Fig. 1).

3 Data analysis

Working with the results, we have applied the **Max aggregated function** to get the highest results for each parameter. Our aim is to understand which method is the best to be used and in what circumstances. That is why we analyzed the methods from the following perspectives: overall effective summary approach; multilingual summary problems and approach versatility; comparison of approach realization and metrics confluence.

After applying the designed algorithm with methods to our datasets, the following results were obtained (see Table 2).

Table 2. Evaluation of the summary approaches. Part 1

Rank	**Language**	**ROUGE-1**	**ROUGE-2**	**ROUGE-L**	**BLEU**	**METEOR**
1	**En**	Luhn 0,8042	Luhn 0,9827	Luhn 0,8042	Luhn 0,5322	TF-IDF (NLTK) 0,59
2	En	Tex-tRank 0,784	Tex-tRank 0,74	Tex-tRank 0,784	Tex-tRank 0,499	LexRank 0,455
1	**Ru**	TF (Spacy) 0,86	TF (Spacy) 0,804	TF (Spacy) 0,86	TF (Spacy) 0,632	TF-IDF (Scikit-Learn) 0,524
2	Ru	Tex-tRank 0,836	Tex-tRank 0,793	Tex-tRank 0,836	Tex-tRank 0,584	Luhn 0,4761
1	**Ro**	TF (Spacy) 0,888	TF (Spacy) 0,822	TF (Spacy) 0,888	TF (Spacy) 0,686	TF-IDF (Scikit-Learn) 0,497
2	Ro	Luhn 0,8363	Luhn 0,7933	Luhn 0,8363	Luhn 0,5824	TF (Spacy) 0,427

As it can be seen, from all the approaches, **the most effective are** *Luhn's heuristic method, TextRank, and Term frequency method.* Having in mind **language sensitiveness**, we can use *Luhn's heuristic method for the English* language and *Term frequency for the Russian and Romanian* languages.

The attention should be paid to the METEOR results. ROUGE

and BLEU results coincide, but METEOR's data differs. From all inputs, TF-IDF approach was frequently selected.

Another group of metrics is given below (see Table 3).

Table 3. Evaluation of the summary approaches. Part 2

Rank	**Language**	**F-1**	**F-2**	**F-L**	**Unit overlapping**
1	**En**	Luhn 0,641	TF-IDF (NLTK) 0,626	Luhn 0,713	LSA/KL 0,33
2	En	TextRank 0,61	TF-IDF (Scikit-Learn) 0,564	TextRank 0,686	TextRank 0,30
1	**Ru**	TF (Spacy) 0,729	Reduction 0,591	TF (Spacy) 0,789	KL 0,38440
2	Ru	TextRank 0,688	Luhn 0,59	TextRank 0,755	Luhn 0,36705
1	**Ro**	TF (Spacy) 0,774	TF-IDF (Scikit-Learn) 0,59	TF (Spacy) 0,827	LexRank 0,36
2	Ro	Luhn 0,687	TF (Spacy) 0,562	Luhn 0,754	Luhn 0,33

Here F-score is based on the ROUGE and BLEU results and Unit overlapping. As we have three types of ROUGE metrics in F-score formula, we will get three types of the F-score. Thus F-1 is for ROUGE-1, F-2 is for ROUGE-2, and F-L is for ROUGE-L.

The last column of Table 3 (Unit overlapping) is calculated based on **Sumy** library that estimates *only its methods*. Thus, not all summary

approaches were taken into consideration.

Looking at the results, BLEU and METEOR provide an average value of around 50% of quality. This is comparable to 50% of the summarized volume of text. In contrast, the ROUGE metric provided results of about 80% of quality. This is normal because these metrics complement each other. You will have high BLEU if many terms from the candidate summary appear in the reference summary, and high ROUGE if many words from the candidate summary appear in the reference summary. The F-score, in this case, provides the common result as a summarization.

As a result, **the most effective approaches** from the second group of metrics are *Term frequency method, Luhn's heuristic method, and Term Frequency-Inverse Document Frequency.* For English sources, *Luhn's heuristic method and TextRank* should be taken; for the Russian and Romanian languages, *Term frequency, TextRank, and Luhn's heuristic method* suit.

Unit overlapping metric emphasizes KL and Luhn's heuristic method in most cases. Unfortunately, this approach of evaluation was implemented in Sumy library for proper algorithms. And we cannot estimate other approaches.

Unfortunately, nothing can be said about the **readability** and **coherence** of the summaries. *The applied metrics cannot estimate these parameters.* Hypothetically, **as language is flexible** and has **different ways of expanding the context of speech**, there are problems **with its preservation during sentence extraction** during the extractive approach. For example, pronouns, link words, etc. Although we have noticed that each summary approach **cuts the original text at different places**, it is impossible to judge its efficacy without an **expert review**.

The number of words, it seems, **does not play an important role** in summary ranking. We had six texts of different lengths, but their summaries *were appreciated with the same high scores as others.* This is because we have indicated the summary length **in percentage**. That is why the ratio of the original text to its summary was always

the same for metrics. **They pay attention only to the amount of corresponding words in both places**. That is not reasonable for extraction-based summarization. Though different scores show that **some differences exist**.

Another thing that should be considered is **summary size**. The shorter the summary, the lower the quality. The results argue for good quality in both cases, with a small difference. More shorter summaries were not taken into account as we pursued the goal of designing **e-course content in the educational area**. The courses should not be too small but contain relevant information for students.

The most productive summary approaches are the Term frequency method, Luhn's heuristic method, and TextRank. However, the language influence on the method list seems to be vague. The **weak point** in all these methods is **tokenization** and **stopwords** list. This topic necessitates more research and experiments for strong conclusions.

4 Conclusion

In this paper, we tried to find effective methods for text summaries from a multilingual perspective. All methods prefer the English language as the default. **Tokenization** and **stopwords** lists seem to **affect the Russian and Romanian languages**. Thereby, such "simple" approaches as TF or TF-IDF have high ranks compared to more advanced approaches.

It should be emphasized that this direction of research should be pursued. Now, the most effective methods are the term frequency method, Luhn's heuristic method, and TextRank.

The research has shown that **we cannot be firmly confident** in summary efficacy relying currently on evaluation metrics. We need some **expert opinion** to investigate such parameters as **readability** and **coherence** of the shortened texts. Only thereafter we can see what **pitfalls** also should be considered and conclude whether extraction-based summarization is good for **e-course content generation** and select the best approach. Also, we should regard some other solutions

as **prompt engineering** and **abstractive-based summarization**.

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The Similarity of Mental and Behavioral Disorders in Epilepsy

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Abstract

The paper presents some results that are oriented to the development of support in the diagnosis of mental and behavioral disorders in epilepsy (MBDE). As a result of the linguistic and formal descriptions of the MBDE research field, a book was developed and a knowledge base of this field was developed. Metric spaces were constructed for evaluating distances between MBDE diagnostics and distance tables. MBDE similarity spaces and similarity tables were constructed. Some scientific results are for the first time and have been appreciated at some international Research and Innovation Exhibitions.

Keywords: Mental and behavioral disorders in epilepsy, knowledge base, similarity space, similarity table.

1. Introduction

According to the World Health Organization (WHO), around 50 million people worldwide have epilepsy, making it one of the most common neurological diseases globally. People with epilepsy and their families frequently suffer from stigma, discrimination, and violations of human rights [1].

Our research is focused on:

- the study with AI techniques of the mechanisms of MBDE remissions, including the obtained by the doctor Al. Popov, one of the members of the research team;

- the development of intelligent support systems to assist doctors in diagnosing patients with MBDE;
- implementing the results obtained in medical practice and achieving an advanced level of quality of life for MBDE patients using the experience of obtaining MBDE remissions.

2. Description of the MBDE Research Area

Informatics effectively contributes to solving problems in various fields of human activity. The implementation of any computerization project starts with the description and formalization of the automated field of activity. In this context, the research team developed the book [2].

The book describes the classification of MBDE, diagnosis, algorithms of conduct, anamnesis, clinical manifestations, paraclinical investigations, treatment, rehabilitation, necessary resources, prophylaxis, and a guide for the patient with MBDE and the persons who assist him.

We denote the set of diagnostics by F,

$$F = \{F_i \mid i = 1, \ldots, 28\},$$

where:

F_1 - F02.8×2 - *dementia in epilepsy*;
F_2 - F04.2 - *organic amnestic syndrome related to epilepsy*;
F_3 - F05.02 - *delirium not superimposed on dementia in epilepsy*;
F_4 - F05.12 - *delirium superimposed on dementia in epilepsy*;
F_5 - F05.82 - *other delirium associated with epilepsy*;
F_6 - F05.92 - *unidentified delirium related to epilepsy*;
F_7 - F06.02 - *hallucinosis in connection with epilepsy*;
F_8 - F06.12" - *catatonic state in connection with epilepsy*;
F_9 - F06.22 - *delusional disorder related to epilepsy*;
F_{10} - F06.30 - *manic psychotic disorder related to epilepsy*;
F_{11} - F06.31- *bipolar psychotic disorder related to epilepsy*;
F_{12} - F06.32 - *depressive disorder related to epilepsy*;
F_{13} - F06.33 - *non-psychotic mixed affective disorder related to epilepsy*;
F_{14} - F06.34 - *hypomanic disorder related to epilepsy*;
F_{15} - F06.42 - *anxiety disorder related to epilepsy*;
F_{16} - F06.52 - *dissociative disorder related to epilepsy*;

F_{17} - F06.62 - *emotionally labile disorder (asthenic) related to epilepsy*;
F_{18} - F06.72 - *emotionally labile disorder (asthenic) related to epilepsy*;
F_{19} - F06.81 - *other psychotic disorders related to epilepsy*;
F_{20} - F06.82 - *other non-psychotic disorders related to epilepsy*;
F_{21} - F06.91 - *undifferentiated psychotic disorders related to epilepsy*;
F_{22} - F06.92 - *undifferentiated non-psychotic disorders related to epilepsy*;
F_{23} - F06.99 - *undifferentiated psychiatric disorders related to epilepsy*;
F_{24} - F07.02 - *personality disorders in relation to epilepsy*;
F_{25} - F07.82 - *other mental disorders of personality and behavior related to epilepsy*;
F_{26} - F07.92 - *undifferentiated mental disorders of personality and behavior related to epilepsy*;
F_{27} - F7×1 - *significant impairment of behavior and intellectual abilities requiring attention or treatment, caused by epilepsy*;
F_{28} - G40 - *Epilepsy without MBDE*, (*control diagnosis*)".

Each diagnosis can be confirmed or denied based on the values of the symptoms and syndromes.

We denote the set of syndromes by S, $S = \{S_i \mid i = 1, \ldots, 17\}$, were:

S_1 - *catatonic syndrome*;
S_2 - *disorders of motor activity*;
S_3 - *quantitative disorders of consciousness;*
S_4 - *abstraction disorders*;
S_5 - *behavioral disorders*;
S_6 - *mood disorders*;
S_7 - *balance and postural fixation disorders*;
S_8 - *thought disorders*;
S_9 - *perception disorders*;
S_{10} - *personality disorders*;
S_{11} - *disorders of the will*;

S_{12} - *speech disorder*;
S_{13} - *neurovegetative disorders*;
S_{14} - *qualitative disorders of consciousness;*
S_{15} - *attention disorders*;
S_{16} - *memory disorders*;
S_{17} - *orientation disorders*.

We denote the set of symptoms with C, $C = \{C_1, C_2, \ldots, C_{163}\}$.

We note that when solving problems in the field of MBDE research, it is necessary to take into account, that the linguistic descriptions of medical concepts can be interpreted differently by different doctors due to the ambiguity and uncertainty of the descriptions in natural languages and the degree of professional experience of the doctors.

3. The knowledge base of the MBDE research domain

We have already mentioned that linguistic descriptions of any field of application, including the medical one, are nuanced descriptions. Therefore, the field of MBDE research has been formalized using mathematical methods.

Inspired by Dimitri Mendeleev's Periodic Table, it was possible to present the MBDE knowledge base with a set of tables hierarchically organized into three levels: diagnoses, syndromes, and symptoms.

Were developed 19 tables to represent the following types of relationships between MBDE concepts:

- $R_{FC}(F, C)$;
- $R_{FS}(F, S)$;
- $R_{FSi}(F, S_i,)$, $i = 1, ..., 17$.

Each of the table types knows three versions of representing the contents of their cells:

- fuzzy numerical values;
- fuzzy symbolic values;
- numerical values and at the same time fuzzy symbolic values.

The first version of the $R_{FC}(F, C)$ table consists of 28 columns and 163 rows. Each column represents a quantitative description of a diagnosis by the values of 163 MBDE symptoms. Column 28 is for the description of the control diagnosis G40 (epilepsy without MBDE).

Each diagnosis column represents a sequence of symptom values C,

$$C = \{C_{i,j},\ i = 1, \ldots, 28;\ j = 1, \ldots, 163\},$$

where $C_{i,j}$ is the degree of manifestation of the symptom with the number j in the diagnosis with the number i.

The table elements are integers in the range [0, 10]. At the request of the beneficiary, these shaded values can be adapted to the ranges [0, 1] or [0, 100] %.

In the second version of the $R_{FC}(F, C)$ table, each element represents a fuzzy symbolic value corresponding to the numerical value in the corresponding cell of the first table. Symbolic values are color-coded and represented as the cell background color of this version of the table.

In the third version of the table, the cell contents are fuzzy numerical values placed in cells on a colored background, where the colored background represents the fuzzy symbolic value of the coded symptom.

Tables for the other knowledge base compartments of the MBDE research domain were similarly developed.

Representing the knowledge base of the MBDE research domain through numerical and symbolic fuzzy values enables intelligent processing by accessing the numerical fuzzy values and/or the symbolic fuzzy values.

4. The logic model of the knowledge base of the MBDE research domain

The MBDE knowledge base can be logically viewed as an artificial neural network (ANN) of the following three layers:

- for entrance – the symptoms;
- hidden – the syndromes;
- for output – the MBDE diagnostics.

In cases where the confirmation or refutation of a hypothesis diagnosis is requested, the inferential process starts from the diagnosis. In these cases, the MBDE knowledge base can be logically viewed as an ANN with the following three layers:

- for input – the diagnoses;
- hidden – the syndromes;
- for output – the MBDE symptoms.

The information of each cell of BC MBDE allows the generation of four types of inference rules:

- deductive inference rules for premises presented by:
  (a) fuzzy numerical values; (b) fuzzy symbolic values;
- inductive inference rules for conclusions presented by:
  (c) fuzzy numerical values; (d) fuzzy symbolic values.

5. Construction of similarity tables of MBDE diagnoses

The MBDE research domain knowledge base contains 5040 cells:

5040 *cells* = 28 *diagnoses* × 180 *symptoms* & *syndromes*.

The computer realization of the family of TPCE problems with conventional computing tools requires the computer development of some structures of the order of 28^{180} nodes. For this reason, it can be predicted that the computer modelling of the MBDE Research Domain involves the risk of the *explosion of combinators.*

The parallel calculation simulation techniques, inspired by membrane computing [6] and used in the present research, allow one to significantly reduce the complexity of the architecture of the developed smart products.

The similarity spaces can evaluate the distances between diagnoses.

Using the respective mathematical tools, it was possible to build similarity tables of MBDE diagnoses.

Definition. (inspired by [7]) The *similarity space* is a couple (X, sim), where X is a non-empty set whose elements are called points, and sim: $X \times X \to$ N an application called *similarity-function* with the following properties:

Sim_1: $0 \leq sim(x, y) \leq 100$, $\forall x, y \in X$

Sim_2: $sim(x, y) = sim(y, x)$, $\forall x, y \in X$ (* *symmetry* *)

Sim_3: $sim(x, y) = 100$, $\forall x, y \in X$ (* *if and only if* $x = y$ *)

The similarity tables of MBDE diagnoses allow a deeper understanding of the mechanisms of manifestation of these diseases. The respective mathematical and informatics tools allowed the construction of similarity tables of MBDE diagnoses.

The tables proposed in the paper can contribute to a more operative, effective, and safer diagnosis of MBDE.

The tables proposed in the paper will also contribute to the development of artificial intelligence systems for the diagnosis and treatment assistance of MBDE patients.

The development of the table of similarities of diagnoses for the BC MBDE $R_{FC}(F, C)$ compartment went through the following stages:

1. We denote by F the set of diagnoses, by $\{F_j\}$ the elements of this set: $F = \{F_j, j = 1, \ldots, 28\}$.
2. We denote by C the set of syndromes, by $\{C_i\}$ the elements of this set: $S = \{C_i, i = 1, \ldots, 163\}$.
3. We construct the MBDE similarity function:

$$T1 = Table[100 - k*sqrt(\sum_{i=1}^{163}(B[i, j] - B[l, i])^2, j, l = 1,..., 28)]$$

where:

- *Table* - *Wolfram Mathematica* function;
- *sqrt* - mathematical function "*the extract of the square root*";
- $B[i, j]$ - the value of symptom i for diagnosis j:

$$i = 1, \ldots, 163; j = 1, \ldots, 28;$$

- B – the relation table $R_{FC}(F, C)$,

$$B = \{B[i, j], i = 1, \ldots, 163; j = 1, \ldots, 28\};$$

- k - the MBDE similarity normalization coefficient. Initially, k receives the value 1 ($k = 1$) and will be adjusted after normalizing the similarities in the obtained table, so that the similarity values after normalization fall within the range [0, 100].

4. It is calculated, using the similarity evaluation function built in p. 3, the MBDE similarity table ordered according to the ICD-10 Classifier of the World Health Organization [4].
5. It is determined the normalization coefficient of the similarity function, constructed in p. 3. As a result of the normalization of the similarity values obtained in the table calculated in p. 4, the value of the normalization coefficient k, $k = 53.9806$, was determined. For this value, the similarities of the MBDE diagnoses fall within the range [0, 100].
6. The MBDE similarity table is calculated repeatedly with the help of the similarity function constructed in p. 3. adjusted to the normalization coefficient obtained in p. 5., i.e. $k = 53.9806$.
7. As a result of the computer execution of stages 1. - 7., the table of MBDE similarities was obtained in their order in the WHO ICD-10 Classifier. A fragment of the similarity table is shown in Table 1.

Table 1. An excerpt from the MBDE similarity table

	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}
F_1	100	84	42	53	52	41	53	57	45	42	38	50	39	42
F_2	84	100	42	57	49	41	57	59	47	43	41	53	40	43
F_3	42	42	100	48	51	55	46	45	48	52	49	58	51	61
F_4	53	57	48	100	66	54	78	71	78	69	63	64	69	65
F_5	52	49	51	66	100	60	69	63	71	74	62	62	64	65
F_6	41	40	55	54	60	100	54	56	58	61	59	62	54	72
F_7	53	57	46	78	69	54	100	74	73	67	62	66	63	61
F_8	57	59	45	71	63	56	74	100	68	63	61	62	58	61
F_9	45	47	48	78	71	58	73	68	100	75	66	61	71	67
F_{10}	42	43	52	69	74	61	67	63	75	100	69	62	72	70
F_{11}	38	41	49	63	62	59	62	60	66	69	100	67	63	69
F_{12}	50	53	58	64	62	62	66	62	61	62	67	100	60	64
F_{13}	39	40	51	69	64	54	63	58	71	72	63	60	100	63
F_{14}	42	43	61	65	65	72	61	61	67	70	69	64	63	100
F_{15}	41	44	48	70	64	58	70	64	71	69	72	65	65	69
F_{16}	50	47	58	60	66	69	58	59	62	64	57	59	58	72
F_{17}	39	38	51	63	62	52	58	54	63	69	57	57	78	59
F_{18}	39	41	52	60	64	50	59	52	64	70	58	58	81	59
F_{19}	34	39	47	69	59	53	63	58	70	72	69	59	74	64
F_{20}	37	41	49	70	65	57	67	60	74	75	71	62	71	69
F_{21}	34	38	43	64	57	54	60	60	66	69	73	58	65	68
F_{22}	29	33	44	59	53	58	56	54	62	63	70	58	59	68
F_{23}	28	32	41	63	54	50	57	54	66	67	69	54	66	64
F_{24}	25	29	41	60	53	50	55	52	64	67	67	53	69	63
F_{25}	28	32	43	62	54	55	57	56	66	69	71	56	67	67
F_{26}	24	25	42	55	53	54	50	50	61	66	64	52	67	63
F_{27}	14	18	34	47	42	41	42	39	52	57	55	43	63	52
F_{28}	0	3	25	29	26	28	23	22	33	41	38	29	48	35

Encoding the fuzzy symbolic values by colors is shown in Table 2.

Table 2. Encoding fuzzy symbolic values of similarities by colors

Fuzzy symbolic value	Range of the fuzzy numeric values	The color coding

Very weak or absent	0 – 20			
Weak	21 – 40			
Average	41 – 60			
High	61 – 80			
Very high	81 – 100			

Then, based on this table, the table of MBDE similarities was developed in descending order of similarities in relation to the control diagnosis G40 – epilepsy without MBDE. Then, similarly, the similarity tables were constructed for the other MBDE spaces.

5. Conclusion

Using the experience of Dr. Al. Popov (one of the authors) in obtaining more than 175 remissions in patients with MBDE, the book [3] was developed and placed on the Internet for free access.

The similarity tables of MBDE diagnoses, developed for the first time, contribute to a better understanding of the mechanisms of manifestation of MBDE.

There were developed 38 similarity tables of MBDE diagnoses and 38 tables of evaluation of distances between MBDE diagnoses.

Developed tables allow more effective diagnoses of MBDE. Clinicians may receive a warning regarding the situation in which the diagnosis concluded based on the symptoms manifested by the patient may be confused with another close to the manifestation.

Similarity and metric tables can also contribute to the development of artificial intelligence systems for the diagnosis and treatment assistance of MBDE patients.

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Application of the Multidimensional Point Distribution Method in Machine Learning Tasks with Imbalanced Data

Vladimir Popukaylo, Anastasiya Shmelyova

Abstract

The article addresses the problem of using imbalanced data in multi-class classification tasks. It briefly examines the main existing approaches and proposes the application of the multidimensional point distribution method to balance classes. The algorithm for applying this method is described, and an experiment is conducted using synthetic data. The results are compared with existing algorithms such as random oversampling of the small class, ADASYN, SMOTE, ASMO, and SVMSMOTE. The article shows the possibility of using the multidimensional point distribution method in principle to improve the quality of machine learning algorithms in conditions of imbalanced data.

Keywords: Machine Learning, classification task, tabular data processing, imbalanced data, multidimensional point distribution method

1. Introduction

Classification is a supervised machine learning method that allows predicting data distribution into a predefined and distinct number of classes. In the real world, most of these data sets are imbalanced, with classic examples being tasks like customer churn prediction, fraud detection in financial transactions, or identifying rare diseases. When one of the classes contains significantly fewer samples than the other classes, it is referred to as the minority class, and the data set is called an imbalanced data set. The property of imbalance of a data set has significantly affected the effectiveness of traditional classification

methods, causing classifiers to lean towards the majority classes [1]. In this article, we attempt to apply the multidimensional point distribution method to increase the number of instances in the minority class, which may lead to improved performance of machine learning algorithms.

2. Literature Review

Let's consider several main approaches for addressing the class imbalance problem at the data level [2]:

1. Randomly oversampling the small class (random oversampling).
2. Randomly undersampling the prevalent class (random undersampling).
3. Informatively oversampling the small class (where no new samples are created, but the choice of samples to resample is targeted rather than random).
4. Informatively undersampling the prevalent class (the choice of samples to eliminate is targeted).
5. Oversampling the small class by generating new synthetic data.
6. Combinations of the above techniques.

Resampling is a commonly used method to address the problem of class imbalance. When applying this approach, there is a need to determine the optimal class distribution and to conduct a resampling of the training data. The simplest resampling methods include removing samples from the majority class or duplicating examples from the minority class. Depending on the desired class ratio, a certain number of random records are for the operation.

However, random oversampling and undersampling may not be sufficient in many cases. If within-class differences represent the class imbalance problem within a dataset, random oversampling can lead to over-duplication of samples in some parts and underrepresentation in others. Similarly, random undersampling may reduce data variability, affecting the performance of some classifiers.

A preferable resampling process involves identifying sub-concepts within a class and increasing the number of samples for each concept separately to achieve a balanced overall distribution. Informative sampling aims to make the selected samples more representative, but it

increases the cost of data analysis, as it requires defining criteria for selecting samples.

Various techniques exist for informative sampling, to increase the number of instances in the minority class by generating new synthetic data, different algorithms are used, such as:

1. SMOTE (Synthetic Minority Oversampling Technique): This algorithm generates artificial instances similar to the existing minority class instances without duplicating them. It creates new records using the K-nearest neighbor (KNN) algorithm. The SMOTE algorithm allows setting the number of records to be generated and adjusting the similarity level by changing the number of nearest neighbors (k).
2. ASMO (Adaptive Synthetic Minority Oversampling): ASMO is a modification of SMOTE that utilizes pre-clustering (e.g., k-means) to improve sampling quality when minority samples are uniformly distributed among the majority class and have low density.
3. Metropolis-Hastings algorithm: This algorithm allows the sampling of any probability distribution function. It is based on creating a Markov chain, where each newly selected value depends only on the previous one.

3. The Multidimensional Point Distribution method

In the paper [3], the Point Distribution Method was proposed, which allows the processing of a small sample and obtaining a so-called virtual or equivalent large sample. Building upon this method, the Multidimensional Point Distribution method was introduced, which can be used to improve the quality of data modeling for small samples [4]. In the work [5], it was also demonstrated that applying this approach preserves knowledge about the probability distribution of the random variable and the magnitude of linear correlation between the studied factors.

Let's consider the potential application of the Point Distribution method in the task of increasing the number of instances in the minority class by generating new synthetic data. We will examine an example proposed in the Python library for addressing the problem of imbalanced

data [6], comparing various oversampling algorithms. For analysis, we will use the sklearn library [7], which allows the creation of clusters of points normally distributed around the vertices of an n-informative-dimensional hypercube with sides of length 2*L. We will generate a dataset with the following parameters:

- Number of samples: 1000.
- Number of classes: 3.
- Class weights: 0.01, 0.01, 0.98.
- Hypercube size (L): 0.8.
- Number of clusters: 1.

We will use logistic regression as the classification algorithm. Figure 1 shows the original data and the decision boundary for the algorithm.

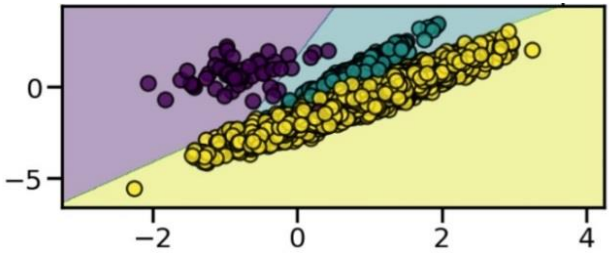

Figure 1. Logistic Regression on the Original Data

In Figure 2, we demonstrate how different oversampling algorithms, such as random oversampling of the minority class, ADASYN, SMOTE, ASMO (K-meansSMOTE), and SVMSMOTE [8], influence the appearance of the decision boundary.

Next, we will perform oversampling based on the Multidimensional Point Distribution method with default parameters (n=30, normal distribution) [9]. To do this, we need to:

1. Isolate datasets related to each of the minority classes.
2. For each of the minority classes, use the Point Distribution Method to construct tables for the calculation of non-normalized probability densities in the virtual region for all Xi. Additionally, construct data tables for each row of the original data using the Point Distribution Method, simultaneously incorporating the values of two columns Xij from the corresponding non-

normalized probability density table and column Xif. Matching of columns Xij and Xif occurs based on the level of maximum non-normalized probability density.

3. Combine the synthetically generated datasets with the majority class. The next step is to perform classification using logistic regression and visualize the results in Figure 3.

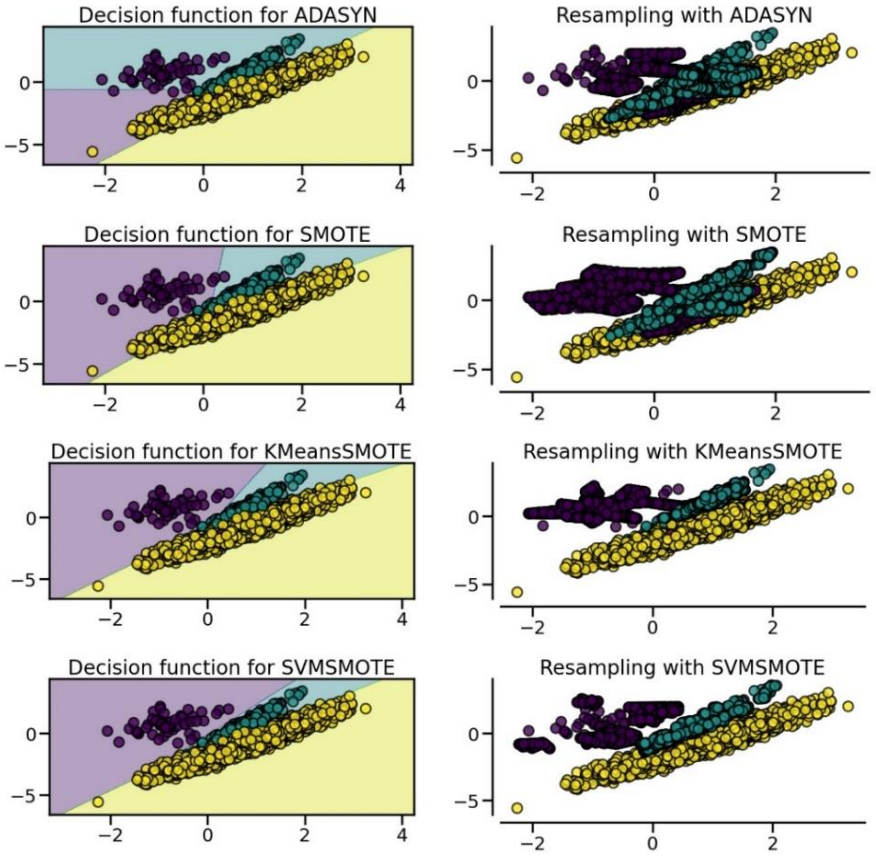

Figure 2. Results of Various Oversampling Algorithms

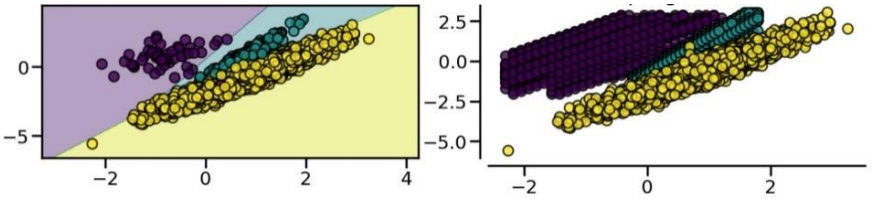

Figure 3. Results of applying the multidimensional point distribution method for data sampling

4. Results Analysis

The presented images demonstrate that applying the multidimensional point distribution method improved the decision-making function by generating synthetic data that resembles the structure of the original objects. However, since the default implementation of the algorithm was used, an excessive amount of data was generated to solve this problem. Table 1 shows the classification performance metrics for the mentioned algorithms:

Table 1. Classification Performance Metrics

Algorithm	**Weighted F-1 score**	**Geometric mean score**	**Index balanced accuracy**
Without sampling	**0.99**	0.91	0.67
Randon oversampling	0.94	0.92	0.85
ADASYN	0.81	0.82	0.67
SMOTE	0.96	0.92	0.85
KmeansSMOTE	0.95	0.93	0.87
SVMSMOTE	0.97	**0.94**	**0.90**
Multidimensional point distribution	0.97	**0.94**	0.89

Analysis of the obtained metrics allows us to draw conclusions about the potential application of the multidimensional point distribution method to improve the quality of machine learning algorithms in the context of imbalanced data. However, beyond this research, the question of the

method's applicability to data of different natures and with different methods of building mathematical models remains open.

5. Conclusion

This article has demonstrated the fundamental potential of using the multidimensional point distribution method to improve the quality of machine learning algorithms in the presence of imbalanced data. In this regard, future research directions may include the automatic selection of point distribution method parameters to achieve the best quality on various datasets, as well as identifying types of problems where this approach can be most effectively used to enhance classification performance.

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On some pre-complete relative to positive expressibility classes of formulas in the 8-valued para-consistent extension of the logic $S5$

Andrei Rusu, Elena Rusu

Abstract

We consider the 8-valued extension of a para-consistent logic $S5$ and establish some necessary conditions for a system of its formulas containing para-consistent negation to be complete in it relative to positive expressibility.

Keywords: para-consistent negation, para-consistent logic, positive expressibility, functionally complete systems of formulas.

1 Introduction

A theory is called inconsistent if it has as its theorems formulas A and $\neg A$ [1]. If a theory derives all the formulas as its theorems, it is called trivial. These two notions are different, but they coincide in familiar to us systems. A theory is para-consistent if it is inconsistent, but it is not trivial [2].

Para-consistent logic is motivated not only by philosophical considerations, but also by its applications and implications. One of the applications is automated reasoning (information processing). Consider a computer which stores a large amount of information. While the computer stores the information, it is also used to operate on it, and, crucially, to infer from it. Now it is quite common for the computer to contain inconsistent information, because of mistakes by the data entry operators or because of multiple sourcing. This is certainly

a problem for database operations with theorem-provers, and so has drawn much attention from computer scientists. Techniques for removing inconsistent information have been investigated. Yet all have limited applicability, and, in any case, are not guaranteed to produce consistency. (There is no algorithm for logical falsehood.) Hence, even if steps are taken to get rid of contradictions when they are found, an underlying para-consistent logic is desirable if hidden contradictions are not to generate spurious answers to queries [3].

Other motivation for investigations of para-consistent logics is the part of artificial intelligence research called belief revision, which is one of the areas that have been studied widely. Belief revision is the study of rationally revising bodies of belief in the light of new evidence. Notoriously, people have inconsistent beliefs. They may even be rational in doing so. For example, there may be apparently overwhelming evidence for both something and its negation. There may even be cases where it is in principle impossible to eliminate such inconsistency. For example, consider the 'paradox of the preface'. A rational person, after thorough research, writes a book in which they claim $(A_1 \& \ldots \& A_n)$. But they are also aware that no book of any complexity contains only truths. So they rationally believe $\sim (A_1 \& \ldots \& A_n)$ too. Hence, principles of rational belief revision must work on inconsistent sets of beliefs. So, a more adequate account can be based on para-consistent logic [4]. Other applications of para-consistent logics are known in robot control [5], in air traffic control [6], in defeasible deontic reasoning [7], in information systems [8] and medicine. Connections between para-consistent logics, adaptive logics and diagnosis are investigated in [9] and [10].

2 The problem

It is a well known class of problems in logic, algebra, discrete mathematics and cybernetics dealing with the possibility of obtaining some functions (operations, formulas) from other ones by means of a fixed set of tools. The notion of expressibility of Boolean functions through other ones by means of superpositions goes back to the works of E. Post [11],

[12]. He described all closed (with respect to superpositions) classes of 2-valued Boolean functions. The problem of completeness (with respect to expressibility), which requires to determine the necessary and sufficient conditions for all formulas of the logic under investigation to be expressible via the given system of formulas, is also investigated. In 1956 ([13, p. 54], [14]), A. V. Kuznetsov established the theorem of completeness according to which we can build a finite set of closed with respect to expressibility classes of functions in the k-valued logics such that any system of functions of this logic is complete if and only if it is not included in any of these classes. In 1965 [15], Rosenberg I. established the criterion of completeness in the k-valued logics formulated in terms of a finite set of pre-complete classes of functions, i.e., in terms of maximal, incomplete, and closed classes of functions.

In the present paper we investigate necessary conditions of completeness with respect to positive expressibility of the systems of formulas of the 8-valued extension of the modal logic $S5$, which contain the para-consistent negation.

The standard language of $S5$ is based on propositional variables and logical connectives: $\&$, $\vee$, $\rightarrow$, $\neg$, $\Box$ and $\Diamond$. We consider the para-consistent negation $\sim$ of $S5$ [16] as follows:

$$\sim a =_{Def} \Diamond\neg a.$$

The logic $S5$ can be considered, according to [16], as a para-consistent logic since it contains a para-consistent negation. The logic $S5$ is characterized by the axioms and rules of inference of the classical propositional logic, the following axioms (A and B are any valid formulas):

$$\Box(A \rightarrow B) \rightarrow (\Box A \rightarrow \Box B),$$
$$\Box A \rightarrow A,$$
$$\Diamond A \rightarrow \Box\Diamond A,$$

and the necessity rule of inference: from A infer $\Box A$.

Consider the set E_k of finite binary strings $(\alpha_1, \ldots, \alpha_k)$, where $\alpha_i \in \{0, 1\}$, $i = 1, \ldots, k$. Define Boolean operations $\&, \vee, \rightarrow, \neg$ over elements

of E_k component-wise, and consider $\Box((1,\ldots,1)) = (1,\ldots,1)$, and put $\Box((\alpha_1,\ldots,\alpha_k)) = (0,\ldots,0)$ otherwise. Also, as usual, $\Diamond x = \neg\Box\neg x$. It is known [20] that $(E_k; \&, \vee, \rightarrow, \neg, \Box, \Diamond)$ represents an algebraic model for $S5$.

They say [17] a formula $F(p_1,\ldots,p_n)$ of $S5$ preserves the relation $R(x_1,\ldots,x_m)$ on the algebra $\mathfrak{B}_k$ if for any elements $\gamma_{11},\ldots,\gamma_{mn}$ of $\mathfrak{B}_k$ the relations $R(\gamma_{1j},\ldots,\gamma_{mj})$ $(j = 1,\ldots,n)$ imply the relation $R(F(\gamma_{11},\ldots,\gamma_{1n}),\ldots,F(\gamma_{m1},\ldots,\gamma_{mn}))$.

Kuznetsov A.V proposed in [18] some generalizations of the notion of expressibility of formulas in a superintuitionistic logic, namely the parametric expressibility, and the existential expressibility (also known as positive expressibility [21]).

The formula F is said to be expressible in the logic L via a system of formulas Σ, if F can be obtained from propositional variables, constants and formulas of Σ applying a finite number of times: a) the rule of substitution of equivalent formulas in the logic L, and b) the rule of weak substitution, which permits, being given formulas A and B, to substitute one of them in another instead of a given corresponding propositional variable [17], [18], [19].

Consider a first-order logic L with $=$ based on the propositional modal logic $S5$. Obviously, any term t of L is some formula G of $S5$ and is expressible via other formulas of $S5$. Elementary formulas of L are $t_1 = t_2$ (t_1 and t_2 are formulas of $S5$). Consider then only positive formulas. Given formulas F_1 and F_2 of L, consider only formulas of the type $(F_1 \& F_2)$, $(F_1 \vee F_2)$, and $(\exists x)F_1$. The notion of bounded and free variables is defined as usual. If a formula F of L has free variables, it defines a relation. A particular case of the relation is the graph of a function.

They say formula F is positively expressible in algebra $\mathfrak{B}$ via the system of formulas Σ if the relation $F(x_1,\ldots,x_n) = y$ is valid on $\mathfrak{B}$ if and only if there is a positive formula $H(x_1,\ldots,x_n,y)$ that is valid over formulas (terms) of Σ.

The system of formulas Σ is said to be complete (with respect to the positive expressibility) in the logic $S5$, if all formulas of the cal-

culus of $S5$ are (positive) expressible in the logic $S5$ via formulas of Σ [17],[18], [19]. The system Σ is said to be pre-complete relative to positive expressibility in $S5$ if it is not complete, and together with any formula of $S5$ which is not positively expressible via Σ the extended system is already complete.

3 Main results

Consider 8-valued topological Boolean algebra $\mathfrak{B}_3$.

Theorem 1. *Classes of formulas preserving on $\mathfrak{B}_3$ the corresponding relations $x = a$ for any element a of $\mathfrak{B}_3$ are closed relative to positive expressibility.*

Taking into consideration that para-consistent negation is not contained in any of the classes from theorem above, we obtain:

Theorem 2. *Consider Σ any system of formulas containing para-consistent negation. In order for the system of formulas Σ that contains the para-consistent negation to be complete relative to the positive expressibility in logic $S5$, it is necessary that on the 8-valued algebra $\mathfrak{B}_3$ the system Σ does not preserve any of the relations $x = a$ on $\mathfrak{B}_3$ for any element $a \in \mathfrak{B}_3$.*

Theorem 3. *Classes of formulas preserving any of the relations $x = (0, 0, 0)$ or $x = (1, 1, 1)$ are pre-complete relative to positive expressibility in the logic $S5$.*

4 Conclusion

We have obtained some necessary conditions for a system Σ of formulas to be complete relative to positive expressibility in the 8-valued extension of $S5$. The next goal is to obtain also sufficient conditions for Σ to be complete. Also, the result has to be extended to the whole logic $S5$. Taking into account the relations between $S5$ and first-order classical

predicate logic, we can try to investigate positive expressibility in it, too. Also, we can investigate the problem of weak-functional systems containing para-consistent negation in other logical systems.

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Challenges and solutions for ill-structured medical data processing in mass casualty situations

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Abstract

In this paper, information solutions with an increased level of intelligence are proposed to assist decision-makers faced with ill-structured problems in their activities in mass casualty situations, taking into account the fragmented and heterogeneous structure of information, data, and knowledge. These solutions should be well-argued based on a personalized approach and not contradict the decision-makers view.

The specific of medical first-aid on disaster sites consists in the necessity under time pressure conditions to triage casualties, based on both vital and sonographic signs. In addition, when addressing medical data processing, the provisions of national guides/protocols should be respected as comprehensively as possible.

Keywords: information technologies, ill-structured domain, medical informatics, medical data processing, mass casualty situations, disaster response

1. Introduction

Ill-structured problems are those that everyone commonly faces in everyday life. These include important social, political, economic, and scientific problems.

Solving ill-structured problems usually requires the following activities: a) problem definition, description, and formalization; b)

generating possible solutions; c) evaluation of alternative solutions, taking into account the end-user preferences; d) implementation of the most viable solution; e) monitoring the implementation.

Knowing the domain and its good description are the main factors in solving ill-structured problems. In addition, there should be identified professional skills and knowledge, that are involved in generating solutions in the decision-making process. All solutions should also have an argumentation component in order to be evaluated later on. Other two important components of solving ill-structured problems are the following: taking into account the decision-maker's view and selecting the solution based on a personalized end-user approach.

Usually, solutions for ill-structured problems are rarely correct or incorrect, but they should fall within a range of acceptances. As a result, in order to be judged, there are needed the stages of testing, implementation, and evaluation based on the arguments.

Therefore, ill-structured problems imply the need for analogical reasoning with concrete cases (precedents) and require the justification of solutions by argument.

The medical diagnostics domain is well known as a domain with diverse and numerous ill-structured problems. Solving ill-structured problems in this domain seems to be more problematic, taking into consideration that currently information, data, and knowledge specific to this domain are unstructured, fragmented, and heterogeneous – which is an additional scientific challenge. This involves studying how to integrate different data sources by using the taxonomies/ontologies associated with these data sources in order to define standardized structures to ensure interoperability and consistency of stored data and knowledge.

In this article, we describe a solution to assist first-aid crews with an adequate response in mass casualty situations. This approach is based on the new possibilities of information technologies, taking into account the domain challenges and expectations of end-users.

2. Medical data processing in disaster response

First aid provided in mass casualty situations involves rapidly responding to emergencies, which can lead to the creation of ill-structured medical data. The chaotic and resource-constrained environment of a disaster site

can make it challenging to maintain standardized medical records. Here are common issues related to ill-structured medical data [1-4] in this context:

- Limited time and resources;
- Lack of access to standardized health records;
- Difficulties in the consolidation of heterogeneous data;
- Limited or no internet connectivity.

These issues can be tackled by the following potential solutions:

- Digital tools or applications for mobile devices;
- Equipment solutions specifically designed for disaster response;
- Standardized templates for essential patient information, vital signs, injuries and provided healthcare;
- Offline work capabilities with the possibility to synchronize data on demand;
- Voice-to-text technology to convert spoken information into structured text;
- Need to follow actual national protocols specific to disaster scenarios;
- Regular trainings of medical aid crews;
- Support via telemedicine consultations;
- Blockchain to ensure trust in the accuracy of medical records;
- Enhancement through post-disaster feedback analysis;
- Measures to protect sensitive information.

Addressing ill-structured medical data in disaster response to mass casualty situations requires a combination of technology, training, and coordination among first-aiders and healthcare organizations. By implementing these solutions, the quality of the collected data can be improved, which in turn enhances patient care and ultimately increases the rate of saved lives.

3. Existing technological solutions and possible challenges

Among the basic information technologies used in medical informatics for medical data processing we can distinguish:

- Case-based reasoning;
- Reasoning based on expert’s knowledge;

- Machine learning models;
- Natural language processing;
- Predictive analytics;
- Operational research models;
- Evidence-based guidelines;
- Sentiment analysis.

However, there exist factors that can even out all the benefits of the used information technologies. It happens when solutions in the medical knowledge-based systems face challenges or do not meet expectations. Here are listed some of the possible challenges:

- *Lack of user-friendly interfaces*: complex user interfaces and non-intuitive design can hinder adoption of the medical knowledge-based systems;
- *Misalignment with clinical needs*: solutions, focused only on technology, but not on meeting specific clinical needs, may not be recognized by end-users;
- *False alarms*: overly sensitive clinical decision support systems can generate frequent false alerts. If the alerts are too frequent or not accurate enough, they can be ignored, resulting in missed critical issues;
- *Inadequate validation and testing*: hasty or insufficient validation of algorithms and acquired knowledge/data under real clinical settings can lead to errors and unfavourable results, undermining trust in the technology;
- *Complex regulatory hurdles*: strict regulatory requirements and protocols can slow down the development and implementation of medical knowledge-based systems, especially if these differ from regional, European, or international ones;
- *Inadequate data security*: security breaches and data leaks in medical knowledge-based systems can lead to the disclosure of sensitive patient information, resulting in privacy breaches and legal consequences;
- *Data bias and discrimination*: artificial intelligence (AI) systems may inherit bias which is present in training data. In medical knowledge-based systems, this can lead to differences in

diagnostics and treatment recommendations for different populations, because AI may be less accurate for certain groups;

- *Overreliance on AI diagnostic tools*: excessive trust (without passing the critical clinical evaluation), as well as complete distrust of the recommendations of decision support systems, can be detrimental to the process of correctly diagnosing a patient.

4. Our approach in support of first-aid response in mass casualty situations

To improve the design, implementation, and regulation (according to national protocols) of medical knowledge-based systems, finding a balance between technological advances, ethical considerations and the needs of health professionals and patients is crucial.

In the development of computer-aided solutions, to support first-aid response in mass casualty situations, there exist two logical approaches: algorithmic and numerical. The numerical approach can be chosen, if developers have access to the set of precedents (real cases).

We have chosen the algorithmic approach, having access to expert data and experts, who can formulate their professional knowledge in the form of decision rules [5].

Reasoning based on an expert's knowledge is an information technology, the most used in the domain of medical informatics because it relies on the acquisition and utilization of the knowledge of medical experts in order to make recommendations for complex and rare diseases, helping less experienced doctors in informed decision-making.

In collaboration with a team of medical experts, we have taken the kernel of the knowledge base, created for clinical sonographic diagnostic, "limiting" it to the injuries of abdominal organs (liver, pancreas, kidneys, and spleen). Also, the knowledge base on the Extended Focused Assessment with Sonography in Trauma (EFAST) protocol, used for sonographic examination in case of mass casualty situations, was created [6].

However, the specific of mass casualty situations is that medical first-aid is focused on managing life-threatening injuries, which should be rapidly identified, and casualties' conditions need to be stabilized before

their safe transportation to the nearest medical centers. In this regard, pre-hospital triage is absolutely essential.

Under time pressure and with limited resources (available healthcare personnel), a quick casualty triage based on vital signs should be done.

Different countries design their triage model for emergencies according to their native medical protocols, resources, and forces. We have studied and analyzed different clinical and emergency guides and protocols, including the national ones – for Moldova [7-8].

We, in collaboration with a team of medical experts, selected basic attributes (casualty characteristics), which determine the decisions for triage based on vital signs, and applied the tabular form as the knowledge representation schema [9].

Also, the minimum set of parameters needed for casualty registration was identified, so that the record, accompanying the casualty, contains all the information, that will enable doctors from specialized medical centers to intervene operatively in the treatment. These parameters cover all stages of the initial assessment of casualty and the organization/structuring of primary medical data. The medical record for casualty registration consists of personal data, time interval, type of injury (resulting from visual inspection of casualty), and values of basic attributes (parameters) that describe vital signs.

In this way decision knowledge and reasoning formalization techniques allowed us to create an efficient inference for casualty prioritizing, based on vital signs [10]. It corresponds to the daily work and habits of the first-aid person on a disaster site, who is the end-user. Being implemented as a web application, it can be used for both teaching and training of paramedics, and for their evaluation (determining the level of knowledge and practical skills).

5. Conclusion

Ill-structured problems are complex real-world problems that do not have clear and well-defined solutions. They are characterized by a high degree of ambiguity and uncertainty and multiple variables that are not prioritized or weighted.

The described approach shows that a knowledge-based system can be especially helpful for solving ill-structured problems, as they use AI

techniques to solve problems due to the use of human knowledge and expertise.

The effectiveness of these solutions depends on the quality of the data, the accuracy of a kernel of the knowledge base, and the ability to adapt to evolving medical knowledge and technologies.

The validation and testing stages show that our approach is a viable one to solve ill-structured problems in the domain of mass casualty situations.

Firstly, there was proposed a knowledge representation schema to acquire and represent expertise and knowledge of a specific subject domain in a structured format (coded rules were developed, facts used in casualty prioritizing were determined, and heuristics and cause-effect relationships related to the problem domain were identified).

Secondly, a logical inference module was developed to help persons in informed decision-making in uncertain and complex situations.

The proposed solution can be used as a tool for gaining expert knowledge – supporting and facilitating the process of acquisition and formalization of expert knowledge in the subject domain, even in situations when this knowledge is explicit or implicit.

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Institutional Mixed Reality Digital Transformation using Digital Twins

Dragoș Silion

Abstract

Mixed Reality (XR) industry is slowly coming to maturity, especially when we talk about isolated, small-scale experiences. However, there is a need to bring this technology to a larger magnitude. We therefore made an overview of medium-to-large institutions and their need for XR Digitization and we came up with the proposal of a layered approach, based on the concept of digital twins, for XR digitization of medium-to-large-scale institutions.

Keywords: Mixed Reality, Digital Twins, XR Digitization

1 Introduction

The mixed reality industry is steadily growing, at least from 2013 to the date of writing this paper. Most usability and technical obstacles were steadily solved. The issue that remains is understanding and choosing the right path in adopting the technology. Medium to large institutions are valid subjects of XR Digitization due to their building-based activity, scale, flow of people, recurrent issues, and access to funding. Even so, deep transformation usually means big budgets, incremental integration, and a general sense of risk from the long-term consequences of the decisions in question. Moreover, many times decision makers have no prior experience in this industry.

We propose therefore a reusable architecture, consisting of a layered set of solutions, based on the inter-disciplinary term of Digital

Twin, that would be a first step in understanding the set of decisions when pursuing deep transformation optimizing time and budgets, and reducing the risk of mistakes.

2 State of the XR Industry

2.1 State of Technology

When we talk about technology, the XR Industry advanced quite a lot in the last decade or so. We can argue nowadays there is not so much a problem of technological innovation, but more one of usability. Therefore, as the processing power of the processing units (both CPU and GPU) kept growing combined with input data from sensors such as cameras, IMUs, LIDAR, and so on, we now have devices capable of most use cases we imagined initially, with few drawbacks that still need research, of course. At the date of writing, there's a wide range of devices, covering many needs, such as mobile devices (through XR software – ARCore and ARKit), AR Glasses (NReal, Vuzix Blade, ThinkReality, Epson), VR Headsets(Meta Quest, PSVR, HTC Vive, HP Reverb), MR Headsets (Microsoft Hololens, MagicLeap, Apple VisionPro) and auxiliary devices (haptic devices, 3D volumetric capturing cameras, eye tracking, etc.).

Regarding data collection, besides the sensors, the industry heavily relies on Computer Vision software techniques, SLAM (Simultaneous localization and mapping) [1] algorithms, 3D scanning, Photogrammetry, and even more recent, AI techniques such as Neural Radiant Fields. Once data is collected, a wide range of understanding algorithms are accessed, for recognizing the position of feature points, planes, more complex geometry, light estimation, depth estimation, face, hands, eyes, or whole body tracking, image segmentation, iconic buildings recognition, and probably many more.

2.2 Layers of XR

As the technology is so varied, there are also many ways of layering the way mixed reality is used. The way we'll choose, as it enables understanding of the importance of institution-level XR, is by scale. From small to global we'd have Human Centric XR, Object-Centric, Building-Level, City-Level, and ultimately, World-Level XR, with different versions ranging from ARCloud to Metaverse (see Figure 1).

Both Human-centric and Object-centric XR have found various applications, many with huge success (see Instagram Face Filters, for instance). However, when we go towards the building level and city level, things get more complicated, as scalable and easy-to-replicate systems are needed. There are few success stories in these areas, most of them government-funded, or applied in large industries, such as the car industry or steel industry.

When we go even larger, worldwide XR, utopic ideas such as the Metaverse, through apps that are rather customizable multiplayer VR experiences than true metaverses (Second Life, VRChat, Microsoft Altspace VR, Meta Horizon Spaces). Another interesting idea is that of ARCloud, a word-wide Augmented Reality geolocated layer over the map of the whole world. Interesting initiatives came around from ARCloud Foundation, Google Geospatial API, and Niantic (creators of Pokemon Go).

3 Institutions

Institutions are mainly placed in medium-to-large buildings, many times on multiple floors, multiple areas, and with a constant flux of people, both recurrent and temporary. They can be schools, university campuses, museums, town halls, airports, or even industrial places, such as manufacturing facilities or factories. Even though different in purpose they do have some common interests, as follows.

Transparency, accessibility, and open data. Especially for public institutions, being accessible to everyone is essential. Some

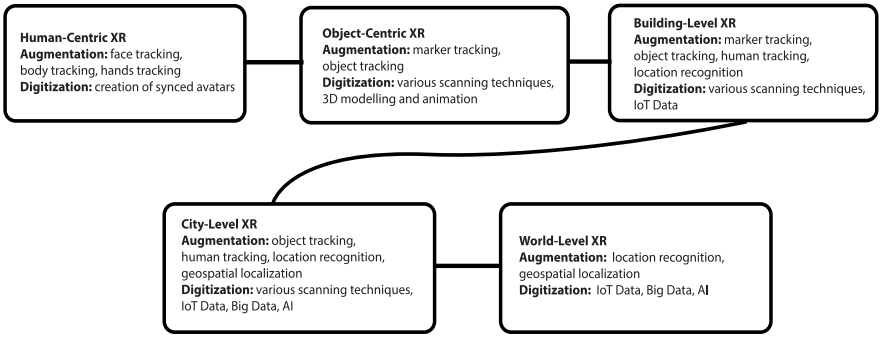

Figure 1. XR Layering

are because of visibility from worldwide tourists, visitors, travelers, or openness towards local citizens, or even employees. Furthermore, having complicated layouts, many times navigation inside the buildings, and finding certain waypoints can easily become cumbersome.

Awareness, Popularity. Many institutions get a large portion of their income from tourists and visitors. Digitization eases access to the institution's offer to the large public all over the world, through the internet. From visiting the VR version of the place, buying tickets online, to asking questions to a chatbot host, all this encourages users to talk about the place, use its services, and visit it physically. [5]

Building Management. Abstracting and visualizing data regarding complex, multi-level buildings, with large flow of visitors and employees can be difficult with traditional 2D methods. 3D Digital Twins and XR-based visualizations can help ease accessibility for people managing this kind of place. [6]

Data-based decisions. Data-based decisions are essential in these places, as they can affect large amounts of people. Usual decisions, such as temporarily blocking a hallway inside an airport or hospital for

maintenance, can have big consequences if done carelessly. Decision-makers, therefore, need advanced, intelligent, real-time tools to avoid any human mistakes and maximize efficiency. [7]

4 Digital Twins based XR Digital Transformation

4.1 Definition

XR Digital Transformation. *We consider XR Digital Transformation the process by which an entity deeply embeds a set of XR technologies to fundamentally change their processes, with the purpose of increased efficiency, ease of communication, and improved data-driven decisions across the business.*

Digital Twin *A Digital Twin is a digital replica of a physical entity, with a two-way dynamic between them. This term floats around emerging technologies such as XR, IoT, 5G, and blockchain, as a central piece of Industry 4.0* [3] [4]

4.2 Proposed architecture

The problem with deep transformation is it's very costly and risky, so, if they lack past experience, the decision-makers need a steady, well-defined, tested workflow to follow, with measurable results. Basically, we need to propose a simple, reusable architecture, that is extendable and offers a wide array of choices based on budgets, timelines, and technological prowess. It should offer safety, and flexibility and base itself on tested assumptions and predictable results (see Figure 2).

4.3 Gathering Data

Gathering information about the physical twin can be done through a wide array of methodologies. For institutional buildings, this can be done, by first gathering the structural information, through different methods of acquiring the physical shape of it, such as manual 3D

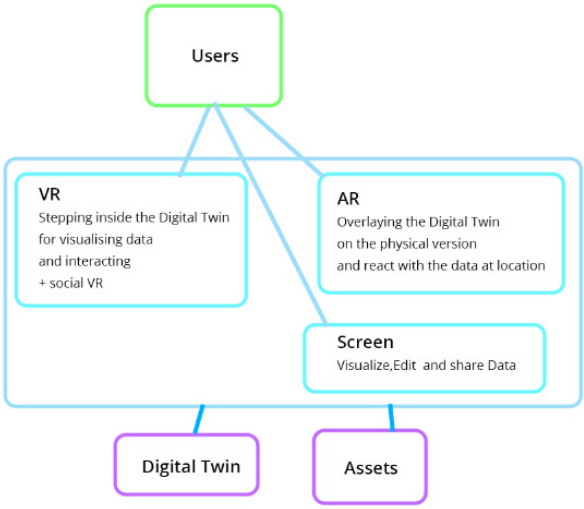

Figure 2. System Proposal

modeling, 3D scanning, photogrammetry, SLAM techniques, or Neural Radiant Fields [2]. For real-time data, all sorts of information can be gathered from IoT sensors(temperature, humidity, pollution sensors), camera feeds, and through several techniques of computer vision and data processing.

4.4 Interaction Layer

Interaction between the digital and the physical twin can be done in zero, one, or two directions. First of all, there is the **static Digital Twin**. This is how things start usually. They require the manual gathering of data, which many times can be laborious, analyzing it and putting the data in the form of a digital twin, applying decisions across the physical twin, and repeating the process.

Automating the process usually starts **one way, from physical to**

digital. In this way, the digital twin is real-time updated by information from sensors. The other way around, **from digital to physical**, is where there is certain functionality across the digital twin that allows for real-time changes inside the physical twin. Of course, the ideal is the **two-way interaction layer**, where ideally, every change happening in any of the two twins instantly affects the other.

4.5 Visualisation Layer

Assuming the digital twin is 3D, it can be visualized through a wide array of devices, from mobile phones, tablets, and desktops, to AR Glasses, MR, or VR Headsets. This decision should be based on the institution's budget, technical know-how, how deep the interaction is supposed to be, number of simultaneous users, ease of communication of the users, and the necessity or lack of it for the users to be in the same geographical location as the physical twin, etc. The digital twin might be visualized on multiple devices at the same time. It can also be accessed as a whole or partially based on each user's interest and authorizations.

There also should be explored different proved formats to store data, from a simple point cloud, to a more complicated BIM model [8], a model used frequently by builders and architects to store multiple layers of interest in a readable, 3D format.

4.6 Assets

Besides structure, each use case needs a set of essential assets that should be accessible to one or more types of users. For example, schools or universities might need access to didactical materials, 3D scans, and tools such as lasers or drawing instruments. On the other hand, a museum might need the 3D scanned version of their assets to showcase, study, and offer as open-source.

4.7 Users

There's a wide array of users that should have different types of access to the acquired data. From admins, with complete access rights, to internal employees, students or clients, and finally, guests such as visitors, tourists, or passer-byes.

5 Conclusion

Digital Twins are still quite an abstract term. It's still defined mostly on the user's needs, and modified accordingly. We ourselves use a more XR-centric definition of it, although there are adjacencies with Industry 4.0, Internet of Things, 5G, Big Data, and more. In this paper, we centralized information regarding a problem and proposed a first-layered solution.

However, the next steps should be in defining and detailing each layer, testing and evaluating our propositions and of course, iterating based on results, taking into account scalability, ease of use, budgets, and efficiency.

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Improving augmented reality experiences for application development

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Abstract

As commonly understood, AR technology offers users captivating and interactive encounters by enhancing digital information onto real-world objects. However, this augmentation doesn't consistently yield the desired outcomes, work as initially intended, or deliver a seamless and satisfying user experience. Various challenges and issues can arise when working with augmented reality methods. In this article, we present solutions to enhance augmented experiences based on our two years of developing educational applications.

Keywords: Augmented reality, artifacts, marker, learning style.

1 Introduction

Augmented reality integration within the realm of education offers students the opportunity to engage in immersive experiences, thereby enhancing the learning process by making it more interactive, efficient, and meaningful. Augmented reality services within the educational and training domain empower users to interact with real-time applications and virtual elements that elucidate and illustrate concepts using multimedia, computer-based simulations, animations, quizzes, etc. This mode of augmented reality education effectively supplements conventional teaching and learning methodologies by fostering critical thinking, elevating student engagement, and enhancing their comprehension.

However, this augmentation doesn't consistently yield the desired outcomes, work as initially intended, or deliver a seamless and satisfying user experience. Various challenges and issues can arise [3] when working with augmented reality methods.

We are a dedicated team of augmented reality enthusiasts, deeply committed to its application in the field of education. We consider that augmented learning is a personalized learning approach that adjusts to the needs of the learner. It offers real-time remediation to help learners better comprehend a subject, encouraging exploration and understanding [5]. This approach leverages technologies that incorporate multimedia and interaction, which researchers, teachers, pupils [6], and students [4] have enthusiastically embraced. Instead of emphasizing rote memorization, learners engage in an adaptive learning process that responds to their immediate context. Augmented content can dynamically adapt to the learner's surroundings and learning styles by presenting text, images, videos, or even audio, such as music or speech. Typically, this additional information is displayed through pop-up windows in computer-based environments.

Over the past two years, we have been actively exploring novel techniques and strategies for integrating augmented reality into educational settings. Drawing from our personal experiences of both setbacks and achievements, we have accumulated valuable insights that we are eager to share in this paper.

2 Challenges and issues in creating augmented reality experiences

The integration of augmentation technology within the education field holds the promise of transforming the learning process for students, but it comes with its set of challenges. As this technology becomes increasingly accessible and sophisticated, it is crucial to contemplate the ramifications for educators and students. One of the most significant hurdles is the cost, as this technology can be prohibitively expensive, and educational institutions often operate within tight budgets. Nev-

ertheless, it is essential to weigh these initial costs against the potential long-term benefits of such investments.

Another challenge is the need for educators to become proficient in using this technology to its fullest extent. Some students may face some troubles and require additional support to effectively utilize the technology. Additionally, educators must remain vigilant regarding potential risks, including cybercrime and data security breaches that could arise from the use of human augmentation technology in the classroom.

Nevertheless, the most significant challenge lies in the development of augmented content itself. In our application's development, which relies on marker-based technology, we encountered the issues described in the following subsections.

2.1 Challenges related to markers and artifacts

We consider markers to be the digital image of a trigger, and the physical one is called an artifact. According to [1], markers with ratings of 2-3 stars can pose problems during the recognition and tracking phases. Vuforia Engine relies on the grayscale version of markers to identify features for recognition and tracking. If the image exhibits low overall contrast and a narrow, spiky histogram, it is unlikely to function effectively as a target image. In our initial set of markers, which were designed using black and white colors, markers received ratings of 2-3 stars after evaluation. As a response to these challenges, we addressed the issues by introducing color and additional features in the second batch of markers, consequently increasing their rating to 4-5 stars. Another set of challenges arose due to the similarity in marker designs, leading to confusion for AR cameras, as shown in Figure 1.

The left marker corresponds to the Pi Symphony augmentation experience, while the right marker randomly triggers the visualization of Pi in the Sky artworks by Micajah Bienvenu [2]. When using either one of these markers individually, AR cameras correctly identify and track the actions with 100% accuracy. However, when the markers

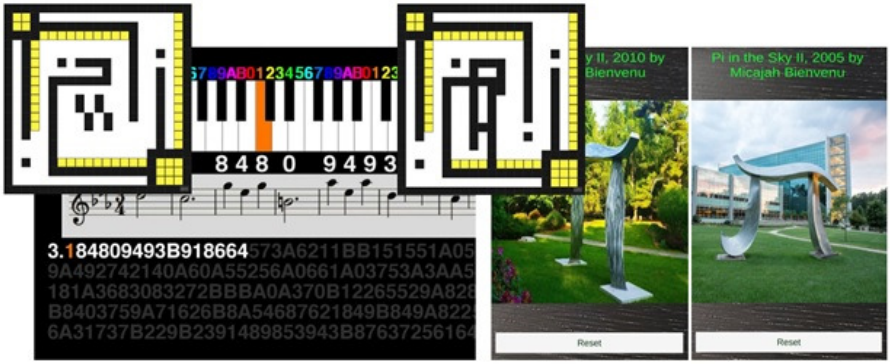

Figure 1. Example of similar markers that are confused

were scanned sequentially, AR cameras triggered both marker scenarios simultaneously.

2.2 Challenges related to augmented learning content

A notable challenge pertains to the diversity of content to accommodate various learning styles and adhere to Bartle's Taxonomy. In order to provide students with personalized content that enables them to learn more effectively, easily, and thoroughly through active engagement, it's imperative to identify areas for improvement. This entails affording students the opportunity to participate in refining the educational content and expressing both positive and negative feedback.

In this context, we conducted an experiment involving students from "Aleco Russo" University in Balti. The experiment involved providing participants with artifacts and mobile applications. Their objective was to test each artifact, which contained various types of augmented scenarios. Subsequently, we granted access to an online survey to gather information. The survey included questions related to the design of the artifacts, the augmented reality learning content, and the performance of the application itself. We collected data on the application's functionality, user satisfaction, and received recommendations

for potential improvements. For example, some recommendations related to augmented scenarios are presented in Figure 2.

2.3 Challenges related to augmented scenarios

Last year, we showcased some of our augmented artifacts at the International Exhibition of Creativity and Innovation, known as Excellent IDEA, which was organized by the Innovation and Technological Transfer Center of ASEM. During this exhibition, we received valuable recommendations for enhancing our scenarios. One particular scenario involved the creation of augmented artifacts for children with disabilities who were attending a children's camp. In this scenario, we aimed to provide an interactive experience showcasing 3D models of both wild and domestic animals along with their associated sounds, as shown in Figure 2 (Wolf v1.0). Subsequently, when we presented this augmented scenario to students from Aleco Russo University, they expressed interest, but they found it to be relatively straightforward. Their feedback prompted us to elevate the complexity of the scenario by introducing features that required user interaction with the 3D model. As a result, we incorporated four buttons that allowed the wolf to perform actions such as running, howling, lying down, and fighting, as depicted in Figure 2 (Wolf v2.0). Each action is followed by a sound.

3 Improvements of augmented reality experiences, solutions

Certainly, designing augmented markers and creating compelling augmented experiences come with their own set of challenges and considerations. Here are some summaries of the key challenges, issues, and solutions related to these aspects of augmented reality:

1. **Marker Design and Recognition:**

    - **Marker Complexity:** Designing markers that are easily recognizable by AR systems while blending seamlessly into

Figure 2. Example of improved scenario

the physical environment can be challenging. Complex or cluttered markers may lead to recognition errors.

- **Solution:** AR artifacts should be designed with clarity and intuitiveness in mind. Users should be able to understand the purpose and functionality of an artifact at first glance. The design should provide visual cues or information to guide users. If certain artifacts are not immediately intuitive, consider incorporating educational elements or tooltips to provide users with guidance on how to interact with them effectively. For example, adding quiz icons for artifacts that contain quizzes.

2. **Environmental Variability:**

- **Lighting Conditions:** AR systems can be sensitive to changes in lighting conditions. Creating markers and experiences that work well in various lighting environments, including low light and outdoor settings, can be a challenge. Our second version of artifacts was laminated with a glossy finish because it makes colors appear more saturated and imparts a professional and refined appearance.

Moreover, glossy laminates excel in concealing fingerprints and smudges, simplifying the task of maintaining cleanliness. However, because of the highly reflective aspect, the AR experiences were difficult to recognize.

- **Solution:** When it comes to laminating artifacts, a matte finish is the preferred choice. It effectively minimizes reflective light, and though it may slightly reduce color vibrancy, it maintains a subtle tactile quality that exudes professionalism. Although matte finish offers less protection compared to gloss and can show scratches and fingerprints, it doesn't pose concerns during recognition and tracking processes.

3. **User Experience:**

   - **User Engagements:** Ensuring that AR experiences are engaging and valuable to users is essential. It's crucial to strike a balance between the novelty of AR and the practicality of the experience.
   - **Solution:** One approach to achieve this balance is to actively engage teachers in the design of AR scenarios. Their input can help craft more effective and beneficial experiences that cater to educational needs.

4. **Content Creation:**

   - **Content Quality:** Creating high-quality 3D models, animations, and interactive elements for AR experiences can be resource-intensive and require expertise in 3D design and development.
   - **Solution:** To enhance the quality and effectiveness of content, one effective solution is to enlist the services of a skilled designer, despite the potential cost involved. Alternatively, you can create your own 3D models and animations, which may be time-consuming but cost-effective. In our cases, we used free 3D models from Unity Assets.

5. **User Interface (UI) Design:**

   - **UI/UX Challenges:** Designing user interfaces for AR experiences that are intuitive, non-intrusive, and accessible can be a complex task. The UI should complement the augmented content and not overwhelm users.
   - **Solution:** To address this challenge, we adopt a minimalist approach, striving for simplicity. Each artifact is dedicated to a single task or lesson, presenting information in manageable chunks. Additionally, for AR scenarios that involve user interaction during movement, the design of artifacts is tailored to adapt to user actions, ensuring interaction without causing confusion.

4 Conclusion

In summary, the utilization of AR technologies in eLearning presents a host of benefits, including heightened engagement, retention, and the flexibility to accommodate remote and adaptable learning. These advantages hold the potential to enhance the quality of education and training while also offering time and cost efficiencies. While there are challenges such as technical complexities, costs, and health considerations, the advantages often outweigh these hurdles.

As research consistently underscores the effectiveness of AR in eLearning, it is evident that these tools will occupy an increasingly pivotal role in the future of education and training. The adoption of these technologies enables us to revolutionize the learning experience, making it more engaging, effective, and efficient for learners worldwide. With the capacity to reshape the landscape of training and development, it is no surprise that AR is gaining prominence in the field of eLearning.

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Decision Support System for Monitoring of Patients with Diabetes

Alexandr Ziziuchin, Victor Ababii, Viorel Cărbune

Abstract

The paper presents the results of the research carried out for the development of a decision support system that allows the monitoring, planning, and administration of insulin doses for patients with diabetes in relation to the quantitative consumption of carbohydrates. The functionality of the system is based on the application of a Neural Network model that is trained based on the data set accumulated in the process of adapting the model to the respective patient.

Keywords: diabetes, neural network, glucose sensor, nutrition and diets for diabetes control.

1. Introduction

Research in the treatment of Diabetes Mellitus has demonstrated the benefit of self-control of blood glucose for the health of patients. The quality of life directly depends on the person's ability to calculate the amount of carbohydrates ingested [1]. Different hardware devices and mobile software applications for diabetes management are being developed to simplify the monitoring procedure [2].

Currently, information technologies are advancing quite quickly including in the field of medicine. In order to cope with all the demands and keep pace with global development, the population tries to compensate for the lack of time through some compromises. Most often, sleep time is limited, the rules of diet and rest are neglected. Nowadays, the world is looking for simple and quick solutions to compensate for the lack of time, but unfortunately, many options are useless and cannot compensate for the damage created.

Today it is difficult to convince a person to create a food diary to keep track of nutrients, prepare meals, or perform some calculations. Patients expect the "miracle pill" from the doctor. Coming out of the specialist's consultation with certain recommendations, which require some calculations, time, or effort, many initially abandon the doctor's instructions and argue insufficient time. They start actively surfing the web in search of the miracle solution that will solve their problem that has been created for years in a moment [3]. Finally, a good part of the patients fall prey to the "miracle" products, aggravating the situation even more.

According to the literature, the diet is respected only by 20% of patients [4]. The situation is complicated for the group of patients with the biggest indication in the regimen, namely people with diabetes. For them, this procedure is the basis of treatment, vitally important, which prevents many complications.

In the present work, some methods are proposed that come to the aid of patients with diabetes to automate the calculation of nutrients and simplify the process of completing the menu, and to help insulin-dependent patients in the calculation of the need for insulin for administration.

Currently, there are many papers describing the use of Neural Networks for predicting glycemic values based on input data. The authors mentioned the fact that for optimal decision support, a data set for training is needed, which describes as much as possible the factors that influence the glycemic fluctuation. Based on these data, maximally effective Artificial Neural Networks can be trained[5].

In order to maintain glycemic values in optimal ranges, it is not enough just to predict blood glucose. A more complex system is needed to predict glycemic values and insulin requirements in patients with type I diabetes. To solve this problem, the authors use simple Neural Networks in combination with Convolutional Neural Networks [6].

The general ideas of the conducted research are oriented towards the development of the decision support system for patients with diabetes. The functionality of the system is based on the application of a Neural Network model learned on the data set obtained from continuous glucose monitoring. The monitoring and decision support process provides for the

record of the quantitative consumption of carbohydrates with the reporting of the need for insulin to cover them.

2. Planning and methods applied in research

Patients who are seen by the endocrinologist with the diagnosis of type I diabetes mellitus will participate in the study. Those who wish to participate must sign the informed consent. Data collection begins in the hospital, where the diagnosis is confirmed, the biochemical parameters are stabilized, the patient is trained, certain particularities of the disease are highlighted, and the insulin requirement is calculated using the mathematical method based on hospital menus [7].

The next stage starts with the discharge of the patient at home. Here the person remains one-to-one with his pathology. The general condition depends a lot on the ability to perform certain food calculations. In practice, very few patients at the initial stage manage to maintain adequate blood sugar. They have difficulty calculating carbohydrates from food intakes, and more complicated is reporting insulin that covers the volume of ingested carbohydrates. To help the patient orientate in all these calculations, the own experimental web application will be used, which presents a system of menus easily reconfigurable and accepted by the patient with the inclusion of the virtual assistant for forecasting blood glucose and calculating the need for insulin in patients with diabetes [8]. The software is accepted by the Departments of Public Health and Endocrinology at the State University of Medicine and Pharmacy.

The application allows you to work with the database of alimentation recommended by the specialist. From the diversity of regimens, the patient selects those that he can implement in practice at the current time, later he develops the skills to operate with food products step by step. The users can edit the menu according to their own needs: adjusting the quantity of products, adding or excluding certain elements. It is possible to completely change the menu without entering item after item because the meals are interchangeable.

The interesting part of the menus selected by the endocrinologist and the patient is the quantitative values of carbohydrates. These are part of the dataset used to train Neural Networks.

The method for collecting blood glucose values will be continuous glucose monitoring [9]. This is a fairly advanced solution in glucose control, which involves the use of hardware devices fixed on the patient's arm that work and provide information during 10 - 14 days continuously. These devices offer the possibility of controlling the parameters at any time of the day and remotely. The data is based on the glucose level in the interstitial fluid. This method creates a delay of about 10-15 minutes between the actual blood glucose readings. The sensor will allow us to obtain glycemic data in certain time intervals of interest, coordinated with the doctor.

The following points are of major interest for the study:

- pre-prandial blood sugar
- blood sugar one hour after eating
- blood sugar after two hours postprandial

After collecting the necessary data, the data set for training the neural networks will be created. The following features will be included here:

- The time of the meal. At different times of the day, the insulin required for a portion of carbohydrates may differ.
- The total amount of carbohydrates administered at a meal. The values correlate closely with the amount of insulin needed.
- The carbohydrate coefficient. It shows the amount of carbohydrates needed for one unit of insulin. It will be calculated separately for breakfast, lunch, and dinner.
- Target glycemic values for some degree of compensation.
- The sensitivity coefficient. It shows the decrease in blood glucose (mmol/l) when one unit of insulin is administered
- Glucose for correction. Difference between current glucose and target glucose.
- Pre-prandial glucose. Glycemic values until food intake.
- Insulin for correction. Theoretical calculation according to mathematical formulas.
- Administered insulin. Calculation of the requirement by theoretical formulas.

As a result of the implementation of the decision support system, our project is in the modeling and testing stage. The data set was modeled and validated by endocrinologists (see Fig.1).

test_id	meal	carb	cf_gluc	target_gluc	cf_sensibilit	gluc_corect	glucoze_start	insulin_corect	insulin
1	1	60	14,5	6,5	2,5	2	8,5	1	5,14
2	2	40	14,5	6,5	2,5	0,5	7	0,22	2,98
3	3	73	14,5	6,5	2,5	-1,5	5	-0,6	4,43
4	4	33	14,5	6,5	2,5	0,5	7	0,18	2,46
5	5	80	14,5	6,5	2,5	1,2	7,7	0,4	5,92
6	6	47	14,5	6,5	2,5	2,5	9	0,83	4,07
7	1	69	14,5	6,5	2,5	-1	5,5	-0,5	4,26
8	2	38	14,5	6,5	2,5	0,5	7	0,22	2,84
9	3	60	14,5	6,5	2,5	4,5	11	1,8	5,94
10	4	70	14,5	6,5	2,5	2,5	9	0,91	5,74
11	5	65	14,5	6,5	2,5	-0,5	6	-0,17	4,32
12	6	63	14,5	6,5	2,5	2,5	9	0,83	5,18
13	1	26	14,5	6,5	2,5	3,5	10	1,75	3,54
14	2	54	14,5	6,5	2,5	3,5	10	1,56	5,28
15	3	25	14,5	6,5	2,5	0,5	7	0,2	1,92

Figure 1. Model data set for training neural networks

The design and testing of neural networks are performed in the Google Collaboratory web application [10].

At the start stage of the project, we worked with the typical neural network, which is part of the MLP (Multi-Layer Perceptron) class (see Fig. 2). It consists of two layers, with a fully connected structure and the activation function is linear.

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_8 (Dense)             (None, 9)                 81

 dense_9 (Dense)             (None, 1)                 10

=================================================================
Total params: 91 (364.00 Byte)
Trainable params: 91 (364.00 Byte)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

Figure 2. The Neural Network Model used in the study

The algorithm optimizer is a stochastic gradient. The mean square error (MSE – Mean Square Error) was used to calculate the error. The

mean absolute error (MAE – Mean Absolute Error) metric [11] was calculated.

3. Analysis of the results obtained

Data obtained from testing demonstrate the effectiveness of multi-layer Neural Networks for predicting the insulin requirement for the food intake of interest. Satisfactory results are obtained when a minimum of 100 samples are collected.

After the adaptation process of the weights consisting of 200 epochs, it shows a mean squared error of 0.067 (see Fig. 3).

```
1 #(Root Mean Squared Error)
2 print('Root Mean Squared Error (RMSE): ', np.round(np.sqrt(metrics.mean_squar

Root Mean Squared Error (RMSE):  0.067
```

Figure 3. The mean squared error of the model

Predicting the amount of insulin on the test set shows values of a maximum overdosage of 0.15 units of insulin and a deficit of a maximum of 0.1 unit (see Fig.4). These volumes are insignificant, if we compare with the rest of the preparation remaining in the syringe after injection of about 0.05-0.1 units.

Finally, we appreciate the experimental neural network model as satisfactory to continue the study on data collected from real patients.

4. Discussions

The research performed helps people with type I diabetes to simplify the calculation of insulin requirements. Medical practice records few successful cases when patients have the ability to calculate insulin requirements after discharge. The inadequacy of the necessary preparation in the body induces the patient into hypo- or hyperglycemia [12]. To prevent such cases, the virtual assistant is connected to the selected menus, which, analyzing the input data, will predict the need for insulin based on the amount of carbohydrates ingested.

1/1 [==============================] - 0s 23ms/step

	Predict	Test_val	Difference
0	5.61	5.61	-0.00
1	2.57	2.42	-0.15
2	3.45	3.36	-0.09
3	4.59	4.56	-0.03
4	2.94	2.97	0.03
5	5.91	5.95	0.04
6	4.37	4.26	-0.11
7	5.64	5.68	0.04
8	4.44	4.43	-0.01
9	4.27	4.20	-0.07
10	7.30	7.39	0.09
11	5.51	5.51	-0.00
12	3.85	3.89	0.04
13	5.51	5.51	-0.00
14	2.92	3.02	0.10
15	2.17	2.16	-0.01
16	5.89	5.92	0.03
17	5.33	5.43	0.10
18	6.50	6.46	-0.04
19	3.67	3.53	-0.14
20	2.94	2.97	0.03
21	5.68	5.67	-0.01
22	5.12	5.21	0.09
23	3.28	3.32	0.04
24	5.50	5.50	0.00
25	3.08	3.02	-0.06

Figure 4. The difference between predicted and test values

This model will only work satisfactorily when the patient is using the continuous glucose sensor. But the given option creates significant

monthly expenses and most patients from the Republic of Moldova will refuse the presented method for financial reasons.

In order to increase the accessibility of patients to our service, the next stage of the project will predict the insulin requirement for administered carbohydrates without knowing the pre-prandial glucose values. The unknown variable will be predicted by Neural Networks trained on individual food menus, taking into account certain eating habits and habits of the patient.

It is important to mention that this mathematical model for predicting the insulin requirement will only be functional for the tested person, with the mandatory condition of strictly respecting the daily regimen. So, for every diabetic patient, a personal Neural Network will be trained.

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